Executive Summary

Background

Gold was mined at the Deloro Mine/Refinery in Deloro, Ontario; arsenic was a by-product of the mining operation. The mining operation and subsequent smelting and refinery processes have been harmful to the environment. Since the 1960s, the Ontario Ministry of the Environment (MOE) has been taking steps to assess and remediate these environmental effects. A 1998 MOE phytotoxicological study, which compared data collected in 1986-87 to existing soil cleanup guidelines (MOE, 1998), suggested that soil in the Village of Deloro located adjacent to the mine site was contaminated with arsenic and cobalt and marginally contaminated with nickel, lead, and silver. In addition, there were historical concerns regarding the presence of gamma radiation and radon gas in the community.

A Technical Steering Committee was assembled by the MOE to evaluate the potential health risk to individuals who lived in the Village of Deloro. The Deloro Village Environmental Health Risk Study Technical Steering Committee consisted of senior scientists from the MOE and the Ministry of Labour, and medical doctors from the Hastings and Prince Edward Counties Health Unit, the Ministry of Health, and the Toronto Hospital for Sick Children. Committee members are shown in Table ES.1. In June 1998, the committee developed a work plan for a health risk assessment for the Village of Deloro to help define the boundaries of contamination resulting from the former mining and refining activities and to look at potential health effects on the community.

Objectives

The overall study objectives were:

- To determine if there are elevated levels of contaminants from the former Deloro Mine Site present in the community in various environmental media (soils, indoor and outdoor dusts, indoor and outdoor air, drinking water, and backyard vegetables).

- To quantify the potential exposure of community residents through: (i) deterministic and, as specified, probabilistic exposure modelling, and (ii) biological monitoring of urinary arsenic in community residents together with a risk factor questionnaire administration and analysis.

- To quantify the potential exposure from contaminated soils/dusts relative to other potential sources of exposure.

TABLE ES.1
TECHNICAL STEERING COMMITTEE

Individual	Association	Expertise
Mr. Scott Fleming (Study Director)	Ministry of the Environment, Standards Development Branch	Senior Toxicologist - human health risk assessment
Mr. Jim Ritter	Ministry of the Environment, Eastern Region	Regional Project Engineer, Deloro Mine Site
Dr. Lynn Noseworthy	Hastings and Prince Edward Counties Health Unit	Medical Doctor, Public Health
Dr. Michael McGuigan	Hospital for Sick Children	Director, Poison Control Centre - biological monitoring of toxics
Dr. Lesbia Smith	Ministry of Health	M.D. -Environmental Health Toxicological Unit, Epidemiology
Dr. Arthur Scott	Ministry of Labour	Environmental Radiation
Mr. Murray Dixon	Ministry of the Environment	Terrestrial Effects Scientist - soil and garden sampling, plant effects
Mr. Adam Socha	Ministry of the Environment	Senior Advisor, Toxicology
Ms. Barbara Theman	Ministry of the Environment, Eastern Region	Communications Specialist
Mr. Glen Hudgin	Hastings and Prince Edward Counties Health Unit	Director, Public Health Inspections

- To quantify to what degree, if any, there may be increased health risks in the Deloro community and to characterize the possible significance of such risks based on exposure modelling and biological monitoring results and comparison of exposure and risk to typical Ontario exposures and risks.
- To use the United States Environmental Protection Agency (USEPA) model for prediction of urinary arsenic levels to compare predicted versus measured values in the community.
- To conduct a thorough information collection and provide a technical summary of applicable risk mitigation efforts and outcomes in other jurisdictions involving contamination of residential communities by arsenic associated with mine tailings or smelter operations.

Study Team

In August 1998, CH2M Gore & Storrie Limited (CG&S) was retained by the MOE to provide overall project management and coordination of this study. With CG&S acting as the prime consultant, a number of expert consultants were retained to assist with different aspects of the study. The Phytotoxicology Section of the Standards Development Branch of the MOE provided expertise and staff for a phytotoxicological study involving soil and backyard vegetable sampling. CG&S performed some of the environmental sampling of outdoor dust and water from private wells. LEX Scientific Inc. (LEX)

was subcontracted to perform sampling of indoor and outdoor air and settled dust. CANVIRO Analytical Laboratories Ltd. and Becquerel Laboratories Inc. were retained to perform analyses of samples for metals and radionuclides, respectively. Goss Gilroy Inc. (GGI) was subcontracted to perform the biological monitoring, to develop and administer a risk factor questionnaire, and to analyze the resulting data. MAXXAM Analytics Inc. was retained to analyze arsenic in urine. SENES Consultants Ltd. (SENES) was subcontracted to perform gamma radiation and radon measurements, and to undertake an exposure assessment for radionuclides. CANTOX Environmental (CANTOX) was subcontracted to undertake the exposure assessment for arsenic and other metals. CG&S assisted in completing the exposure assessment associated with trespassing on the mine site both for metals and radionuclide exposure and provided an overview of the technical direction to the risk assessment team. CG&S was also retained to complete this technical summary report, which contains the key relevant findings of each of the studies as well as an overall discussion of the harmonized study results.

Study Design

The study was a major environmental sampling and health study that was supported by a predictive risk assessment for metals and radiation. The scope of this health study went far beyond the requirements for site-specific risk assessment (SSRA) under the MOE Guidelines for Use at Contaminated Sites in Ontario (February 1997) (GUCSO). The findings cannot be extrapolated for risk management purposes based on strictly SSRA results at sites subject to GUCSO. The findings add to the body of knowledge regarding arsenic in soil and community exposure and can be used to shed light on whether such studies should be undertaken in similarly contaminated communities.

When designing the study, the Technical Steering Committee considered all available technical information concerning the Village and the mine site. The Committee also looked at similar studies that had been conducted elsewhere and gave consideration to historical concerns in the community such as radon gas in homes. Various experts were consulted and additional suggestions were made by the expert consulting team.

A focus questionnaire was developed and completed by several Deloro residents.A door-to-door survey was also conducted to identify those willing to participate and to gather valuable information regarding personal activities in the village that could affect exposure. All information was used to focus the sampling and analysis to ensure that those factors that were most significant would be studied most intensely.

The study in Deloro is the most comprehensive of its kind ever conducted in Ontario. More than a thousand samples were collected over an eight-month period, including:

- sampling of all possible pathways of contamination: indoor and outdoor air, indoor and outdoor dust, soil, drinking water, and backyard garden vegetables;
- more than 175,000 gamma radiation readings; and
- biological monitoring (direct measurement of body arsenic through collection of urine samples) in Deloro and in a comparison (non-exposed) community: Havelock, Ontario. Total and speciated arsenic were analyzed.

The safety of the residents of Deloro was of the utmost importance. Residents were assured during the sampling and analysis of health study results that any samples that indicated an immediate health hazard would be reviewed with the medical doctors on the Technical Steering Committee and communicated immediately to the affected parties. The experts did not find any results that suggested a need for immediate intervention.

The study uses a multimedia health risk approach. The multimedia approach to health risk assessment examines total exposure to contaminants through a number of possible pathways, such as air, soil, drinking water, and food. By examining the various means of exposure, as well as the levels of exposure to a contaminant, the study not only predicts the likelihood of a health risk, it also helps to identify actions needed to reduce that risk. It does not, however, provide a diagnosis of the present health status of people living in the community.

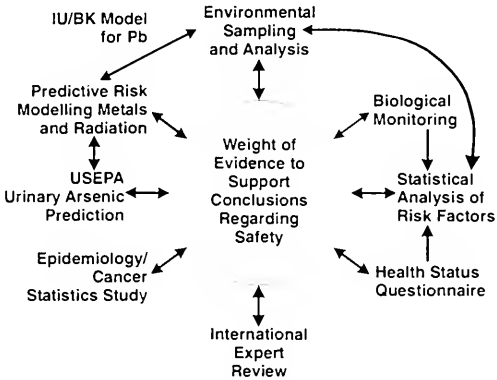
Using this risk approach, information gathered through environmental and biological sampling and the exposure assessment is compared against the most recent toxicological information such as available health-based guidelines for a particular substance. This information is gathered from various agencies (the World Health Organization [WHO], Health Canada, the International Agency for Research in Cancer [IARC], and USEPA, among others) to determine the existing acceptable intake or known health criteria for a substance. The purpose is to predict the relationship between exposure to a contaminant and the likelihood of adverse effects. That is, at what dose (or intake) level are harmful effects likely to occur? Are the calculated risks negligible (minimal) or are they large enough to warrant concern?

In addition to these basic features, an analysis was undertaken to review cancer incidence and mortality rates in Deloro and the population of the surrounding area (including downstream along the Moira River) from 1980 to 1995. The site-specific cancers studied (e.g. lung, bladder, kidney, etc.) were selected because they had been identified in the literature as being potentially associated with the contaminants present at the Deloro Mine Site or because they were relatively common cancers that could provide useful comparisons.

Also, a special environmental health risk factor questionnaire was designed and administered to Deloro (and Havelock) residents to examine possible relationships among levels of arsenic in urine and many different environmental factors including arsenic in soil and dusts, house characteristics, presence and use of a vegetable garden, pesticide use, use of well water, swimming in Moira Lake, presence of pets in the home, occupational exposure, and child's environment.

The major components of the study and details of their interrelationship are provided in Figure ES-1.

FIGURE ES-1
MAJOR STUDY COMPONENTS



The interpretation of the overall findings and summary conclusions used a *weight of evidence* approach. In other words, all of the analyses and expert advice was carefully examined in support of an overall conclusion regarding the safety to reside in the Village and its homes. In particular, the biological monitoring results of the Deloro residents were compared to the monitoring results of the control community and the detailed health status questionnaire data. A robust statistical analysis of risk factor information was completed to examine if there was a correlation between media sample results and levels of arsenic in urine. Cancer statistics were studied as part of an epidemiological review of cancer incidence and mortality data in Deloro and the surrounding area. Predictive multi-media risk modelling was completed. The USEPA model for predicting urinary arsenic was used and the results were compared to the measured urinary arsenic levels. A comparison of measured soil lead levels to those considered using the Integrated Uptake/Biokinetic Model (IU/BK) was also completed.

This study considers historical, present, and future time frames. The epidemiology and cancer statistic study examines historical effects; present exposure is evaluated by the urinary arsenic and health status study, while future effects were determined using predictive exposure models.

The model parameters selected were considered realistic and conservative. The most conservative toxicological criteria were used. Conservatism was introduced by applying large uncertainty factors to limits for chemicals with threshold-type dose-responses. In the case of arsenic, there are concerns that the oral cancer potency for arsenic, based on exposures of Taiwanese populations to arsenic in drinking water, may significantly overestimate skin cancer risks at lower exposure levels more representative of those experienced by the general North American population.

All of the study findings were carefully reviewed by leading international experts from Canada and the United States.

Based on the evidence from all sources, an overall conclusion was established.

Peer Review Process

Leading international experts from Canada and the United States reviewed the study reports and findings. This meticulous review was conducted to ensure that the findings were scientifically correct and to ensure that no important information or interpretation had been overlooked. Overall, peer reviewers were in concordance with the study design and findings. External peer reviewers are shown in Table ES.2.

TABLE ES. 2
EXTERNAL PEER REVIEWERS

Individual	Association	Expertise
Dr. Charles Abernathy	U.S. Environmental Protection Agency	Toxicologist - arsenic health effects and drinking water
Dr. Bliss Tracy	Health Canada	Radiation Scientist - exposure and health effects of radiation
Dr. Willard Chappell	University of Colorado	Professor of Physics - arsenic exposure and health effects
Dr. Chris Le	University of Alberta	Associate Professor, Public Health - arsenic exposure and urinary analysis
Dr. Buck Grisson	Centre for Disease Control, ATSDR	Toxicologist - arsenic exposure and risk assessment
Dr. Henry Caplan	University of Saskatchewan	Professor of Physics - environmental radiation and risk
Mr. Mark Gardiner	Low Level Radioactive Management Office, Port Hope	Radiation sampling and remediation

Key Study Findings and Conclusions

The following major study findings are presented and conclusions made based on this study:

1. Sampling indicates that there are elevated levels of arsenic, cobalt, and lead in soils and above-background levels of other contaminants including radon and gamma radiation in some localized areas of the village.

2. The results of the risk study strongly indicate that there are no unsafe exposures or adverse health effects associated with the contamination in the village. Although the levels of arsenic and other metals were found to be elevated, the analysis and expert advice supports the conclusion that under the range of conditions considered, it is safe to reside in the village and its homes.[1] The most important facts in support of this overall conclusion are listed below:

    - The residents of Deloro do not appear to have, on average, higher levels of arsenic (total and speciated) than the comparison (control) community. Regression analysis showed that the urinary arsenic levels (total and speciated) could not be statistically associated with the characteristics of the population.

[1] Safe in this context means negligible risk Safe is arrived at based on comparison to what is typical (i e there is no meaningful difference).

- The levels of arsenic in urine in Deloro are not indicative of any excess levels of morbidity as observed by their self-reports.
- Characteristics of the places of residence, including the presence of vegetable gardens and use of well water, as well as length of residence in Deloro, were also analyzed using a linear regression. None of the regression coefficients were statistically significant. In addition, the respondents with high levels of arsenic were compared to those with lower levels and none of the variables showed statistically significant association.
- Overall predicted exposures and risks for arsenic were only slightly greater when compared to estimates for the typical Ontario resident. For example, the totalled predicted maximum cancer risk for arsenic in Deloro from all pathways was less than 0.2 times higher than the maximum risk (99^{th} percentile) for a typical Ontario resident arsenic exposure (1.17 per 1,000 for Deloro versus 0.963 per 1,000 for Ontario). Most importantly, the percent contribution of exposure or dose from soil and dusts (dermal, ingestion, and inhalation) was small when compared to arsenic in the normal daily diet. The presence of arsenic in the Ontario diet is due to its natural occurrence as a trace element in the earth and its uptake into crops. There are also various forms of arsenic in food that are considered non-toxic or less toxic than other forms.
- If all soils in Deloro were replaced with background soils, overall arsenic risk would be reduced by only 2 to 4%.
- Predicted cancer and non-cancer risk levels for arsenic were only slightly higher for Deloro residents than for individuals living elsewhere in Ontario. For example, it was estimated that roughly 80% of lifetime exposure to arsenic in Deloro is from the normal Ontario food basket, as compared to roughly 4 percent for soil and indoor dust combined. The combined risk from soil, indoor dust and home-garden produce is one tenth that of the regular Ontario food basket. Furthermore, the levels of risk for each of the soil and indoor dust, and backyard vegetable pathways were found to be in the range that is considered negligible.
- Deloro residents would not experience risks from exposure to lead that were significantly greater than typical Ontario residents would experience. No adverse health effects would be expected to occur at the levels of lead found in the village, as these levels were not unusually high.
- Levels of cobalt and silver in the Village of Deloro are not high enough to result in any measurable health risk. Risks from exposure to nickel in Deloro were comparable to risks for typical Ontario residents.
- The levels of contaminants in drinking water were well below Ontario Drinking Water Objectives for safety.
- The epidemiological review of cancer incidence and mortality data in Deloro and surrounding areas (1980-1995) found that, for the cancers studied, no incidence or mortality rate was high enough to warrant more detailed analysis of the statistics.

- Radiological exposures and lifetime cancer risks predicted for Deloro residents are comparable and in the range of exposures and risks from background radioactivity

3. With respect to gamma radiation, there was one area (the vacant lot adjacent to the main entrance of the former mine site) that exceeded the 1977 Task Force Federal/ Provincial guideline, but the levels were deemed not to be an immediate health concern. In the rest of the village there were only three small pockets (covering an area of no more than a few square metres) with slightly elevated gamma radiation levels, all well within safe levels.

   All radionuclides in soil and dusts were within the range that is typical for the rest of Ontario. A few homes were found to have higher than normal levels of radon gas, although none were above guidelines that require immediate remediation or suggest imminent hazard to health.

Specific study findings and conclusions are provided below.

Sampling Program

Soil Study

A total of 145 soil samples were collected from the front and back yards of all residential properties in the Village of Deloro, as well as from six properties north of Deloro Dam road and two properties west of the village, and tested for contaminants.

Soil samples in the Village of Deloro had higher arsenic, cobalt, and lead concentrations than the MOE's soil guideline values. Exceedance of these guideline values indicates the potential for an adverse effect and warrants further investigation or cleanup of the site. Maximum soil concentrations of barium, copper, nickel, silver, strontium, uranium, and zinc were above typical background levels for Ontario. However, in terms of average concentrations, only nickel and silver concentrations were above typical background concentrations. These maximum and average values were all below MOE guideline values and, therefore, no further investigation is indicated.

Radionuclides in soil were within the range that is typical for Ontario.

Garden Soil and Produce Study

Garden vegetables and garden soil samples were collected and tested for contaminants from nearly all residential households where there was a substantial garden from which vegetables could be eaten regularly. Vegetables were planted from seed in seven Deloro gardens and vegetables were planted from seed in a field plot at the MOE phytotoxicology laboratory in typical Ontario soil.

Soil samples from the gardens were found to contain, on average, arsenic levels approximately twice as high as the MOE guideline value. Cobalt, barium, lead, nickel, silver, and strontium were approximately two to four times higher on average than the upper limit of typical background levels in Ontario. Sampling of garden vegetables showed no significant uptake of contaminants into the vegetables.

The edible portions of plants seldom accumulate high concentrations of arsenic, since plant growth is usually severely stunted before this occurs. The highest arsenic concentrations tend to be in root crops, particularly beets and radishes. Fruit crops, such as tomatoes, berries, and apples, present a much lower risk because they take up and store very little arsenic. Green beans are good indicators of arsenic availability in soil, since this species is particularly sensitive to arsenic. If green beans grow well in a garden, it is unlikely that the uptake of arsenic into other vegetables in the garden will be high enough to pose a health risk. Bean pods, beet roots, carrot roots, and lettuce leaves were sampled and showed no significant uptake of contaminants. Levels of uptake of arsenic into plants were low and indicated that arsenic in Deloro soil is not readily available.

Drinking Water Data

The Village of Deloro municipal well and private wells from 15 participating residences were sampled and tested for the presence of contaminants.

The municipal well water is safe, since all testing met the Ontario Drinking Water Objectives.

First-draw and flushed water samples were collected from each of the private wells. None of the flushed private well samples exceeded guidelines for metals or radionuclides. Two private wells detected lead in first-draw (unflushed) samples that was above Ontario Drinking Water Objectives. This is typically a result of water piping containing lead alloys, which is the reason Health Canada recommends running tap water prior to drinking.

Indoor Air and Household Dust Data

The sampling locations for the indoor air and dust sampling consisted of 54 households, the Town Hall/Library, the municipal well pumphouse, a youth centre in the Village of Deloro, and the Marmora Township office.

The levels of metals and radiological contaminants in indoor air and dust were compared to provincial and federal guidelines (where available) and reference samples collected outside the study area (control locations). Reference samples were taken for air and dust at the Marmora Township office and at the southwest edge of the Village of Deloro. Levels of metals and radiological contaminants in general were not significantly different than levels in samples collected outside the study area (reference locations).

Outdoor Air and Dust Data

The surface dust data were used primarily for comparative purposes since they appeared consistent with the soil data (i.e. higher concentrations of contaminants in dust were generally found in areas of higher soil concentrations).

Ninety-eight air samples, ten road dust, ten exterior surface dust, and ten outdoor dustfall samples were collected and tested for the presence of contaminants. Eight air and dustfall sampling locations were located throughout the village and two were located outside the study area to represent reference areas. The reference areas were the Marmora Township office and the southwest edge of the Village of Deloro.

Outdoor Air. Approximately half of the outdoor air samples detected metals, but all were below provincial air quality criteria. All of the samples detected some radionuclides and, although there are no specific criteria for comparison, the values were in the range of background levels.

Road Dust. Most of the road dust samples detected metals (with the exception of silver) and radionuclides. These values were used for comparative purposes and appeared consistent with the soil data.

Exterior Surface Dust. Metal levels for exterior surface dust were not significantly different than those found at the Marmora Township office. These values were used for comparative purposes and appeared consistent with the soil data.

Outdoor Dustfall. Of the ten outdoor dust sample locations, only two locations detected arsenic. Both of these sample locations were adjacent to the Deloro Mine Site. Lead is the only contaminant with a dustfall criterion value. The value measured for lead did not exceed the lead dustfall criterion. These outdoor dustfall values were used for comparative purposes and appeared consistent with the soil data.

Comparison of Field Data

The results of all environmental sampling for metals and radiological contaminants were compared to assess whether there were trends. There were few trends observed; no one group of individuals in the village was considered to be more exposed to arsenic or other metals than another. Levels of metals in soil do not necessarily increase with proximity to the mine site. For areas where higher concentrations of arsenic were observed (such as the middle of the village), higher concentrations of cobalt, lead, nickel, and silver were also observed.

Radon Gas

Fifty-seven homes were sampled for indoor radon gas. The results indicate that the living areas of 10 residences and the Deloro pumphouse have or may be close to having radon gas levels higher than the 1977 Federal/Provincial Task Force guidelines for radon, although within the range of variability of typical levels in Ontario. It is important to note that while the radon levels approached or exceeded the 1977 Federal/Provincial Task Force Criterion, none of the measured values exceeded Health Canada's radon guideline, considered to represent a level at which remediation actions should be taken.

Outdoor radon gas was measured at 11 locations (10 places within the village and one in Marmora). For outdoor radon gas, the levels were typical of Ontario background conditions.

Gamma Radiation

More than 175,000 gamma radiation measurements were recorded. Gamma radiation surveys were conducted on 63 participating residential properties. Surveys were also conducted on the village park area and baseball field located west of O'Brien Road; the property near the Deloro Pumphouse; the Community Hall/Library building rear yard; the accessible portions of the vacant lot near the main gate to the former mine site; along the rear laneway east of O'Brien Road; along the Deloro Dam roadway; along a series of recreational trails located to the east of the main village; along the western perimeter

fence line of the former mine site; and in several open fields adjacent to the homes in the northern part of the study area.

The 1977 Federal/Provincial Task Force guidelines for gamma radiation were exceeded on only one property, specifically the vacant lot near the main entrance to the former mine site. The radiation levels decrease rapidly with distance from the mine site. The estimated radiation dosage for current conditions is not a health concern.

Three areas (4 to 15 m^2 in size) of elevated gamma radiation levels were encountered in the village. These levels were below the 1977 Task Force criteria.

Biological Monitoring

In order to determine if residents are exposed to contaminants, the following items were conducted:

- Tests for arsenic in urine for those Deloro residents willing to participate in the study, and for participants in a comparison community, Havelock, Ontario. Arsenic in urine is recognized in the medical community as the best indicator of recent environmental exposure to arsenic.
- An environmental health and risk factor questionnaire was administered to Deloro residents to profile the socio-demographics, health, environmental characteristics and diet patterns for comparison with the arsenic in urine data to determine if there were relationships. This process included a robust statistical analysis.
- Prediction of exposures for adults and children through multi-pathway exposure analysis using the most current modelling methods available.

Urinary Arsenic Study

A biological monitoring program was conducted to measure and assess the health significance of environmental exposure to arsenic. The program involved urinary arsenic tests, administration of a detailed risk factor and health status questionniare, and determination of total and speciated arsenic levels in urine. It has been acknowledged in the literature that much of the total arsenic could be a measure of exposure to organic sources (e.g. seafish meal), and these sources possess no danger to the health of a person. However, speciated (inorganic) arsenic is identified in the literature as potential cause for concern, at least with respect to some acute symptoms and some chronic diseases. It is this latter measure that was the main focus of the urinary arsenic analysis. Urinary arsenic tests are recognized in the medical community as the best method of measuring recent environmental exposure to arsenic. It is also the most sensitive for looking at low level exposures and the actual bodily dose to people. It is also the only method for which the health significance of the levels can be judged, because some guidelines exist for total arsenic and there is information on speciated arsenic that can serve as a benchmark for health interpretation.

Havelock, Ontario, was chosen as a comparison community (i.e. control) for the urinary arsenic tests since it is far enough away from Deloro to not be affected by mine activities. Participation in the biological monitoring component was voluntary in both communities. There was a very high participation rate in the study, which meant the

community was well characterized, uncertainty was reduced, and reliability in the overall findings for the Village of Deloro was increased.

Urinary Arsenic Tests

Urine samples were collected from 121 volunteers in the Village of Deloro (8 out of every 10 people participated) and 53 volunteers from Havelock. An environmental health risk questionnaire (completed for 140 volunteers for Deloro and 54 volunteers from Havelock) was used to determine if there was a link between urinary arsenic levels and information obtained from the risk questionnaire such as diet, source of drinking water, occupation, and length of residence. Since almost the entire population of Deloro and a good representation of Havelock were included in the study, the results are considered quite reliable for a study of this nature.

Overall, the urinary arsenic results for both total and speciated arsenic analyses for Deloro and Havelock were well below those normally associated with adverse health effects. There were, however, in both communities, a few people (four in Deloro and one in Havelock) whose results for urinary arsenic were slightly above the normal range. Detailed analysis of the reported environmental health risk information from these residents showed no adverse health effects or unusual exposures. However, as a measure of prudence, the health experts on the study team advised these individuals to consult with their family doctors. In addition, comprehensive information packages were provided to each individual's family physician.

Levels of arsenic in urine (total and speciated) in Deloro residents are essentially the same as those in the comparison (non-exposed) community. The distribution of urinary arsenic levels in Deloro residents was also very similar to the distribution in Havelock residents and there was no statistical difference in mean values for all the arsenic results between the two communities. In short, there was nothing unusual about any of the urinary arsenic findings.

Therefore, there was no meaningful difference found in levels of arsenic in urine between Deloro and the comparison (unexposed) community of Havelock, a town where there is no known arsenic contamination. In other words, arsenic exposure in Deloro is essentially that of a community where no environmental arsenic exposure is expected.

The levels of arsenic in urine in Deloro are also not indicative of any excess levels of illness (as observed by the Deloro/Havelock residents' self-reporting). In other words, there was no relationship between the level of arsenic in an individual's urine and whether or not he/she had reported some kind of health problem on the questionnaire.

There was no demonstrable relationship between arsenic levels in residential yards and garden soil and arsenic levels in people's urine. In other words, higher arsenic values on a property did not lead to a higher urinary arsenic level in the resident(s) of that property.

There was no demonstrable link between levels of arsenic in urine and characteristics of the residents such as the length of time living in Deloro, age, income, education, location of residence, use of vegetable gardens, and use of well water.

The average levels of arsenic in urine of residents from Deloro were much less than the averages reported for other people exposed to significant sources of arsenic (such as mining/smelting, occupational, etc.) as reported in the scientific literature.

Predictive Exposures and Risks

In order to determine if health effects could result from exposure to some levels of contaminants, a predictive risk assessment was completed. The risk assessment predicted potential future health effects. It provides additional supportive information that was integrated with the biological monitoring components of the study to examine recent exposure and the epidemiological component, which looks at historical effects.

Arsenic and Other Metals

Everyone in Ontario is exposed to arsenic, lead, and other metals and has a certain level of risk. This is because trace elements like arsenic are present in our environments wherever we live. When people living anywhere are exposed to arsenic, the greatest potential health risk is the development of skin cancer and, to a lesser degree, lung cancer. Studies elsewhere have also shown that high arsenic exposures are associated with internal cancers such as bladder cancer.

Exposure and risk estimates for Deloro residents were compared to the exposure and risk estimates for typical Ontario adults and children and it was found that overall exposures to arsenic were only marginally greater for Deloro. Figures ES-2 and ES-3 show the contribution of various pathways to intake of carcinogenic arsenic for the preschool child and adult Deloro resident, respectively, as compared to the typical Ontario resident based on the probabilistic mean. The majority of the exposure for both the Deloro resident and the typical Ontario resident is from the general food basket (approximately 95 percent for the typical Ontario and 80 percent for the Deloro child or adult). Most importantly the percent contribution of exposure or dose from soil and dusts (dermal, ingestion, and inhalation) was small when compared to arsenic in the normal daily diet. The presence of arsenic in the Ontario diet is due to its natural occurrence as a trace element in the earth and its uptake into crops. There are also various forms of arsenic in food that are considered non-toxic or less toxic than other forms. Overall predicted risks for arsenic were only slightly greater when compared to estimates for the typical Ontario resident. For example, predicted maximum cancer risk for arsenic in Deloro from all pathways totalled was approximately 0.2 times higher than the maximum risk for a typical Ontario arsenic exposure (1.17 per 1,000 for Deloro versus 0.963 per 1,000 for Ontario).

FIGURE ES-2
CONTRIBUTION OF VARIOUS PATHWAYS TO PRESCHOOL CHILD RECEPTOR EXPOSURE TO ARSENIC (PROBABILISTIC MEAN)

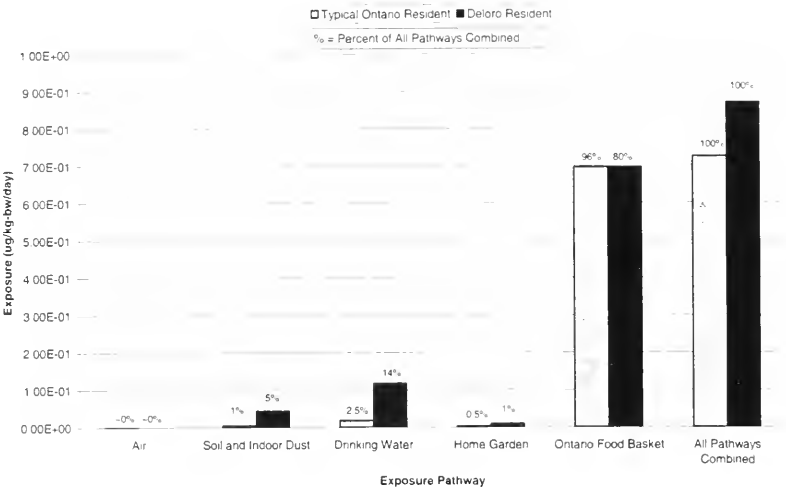
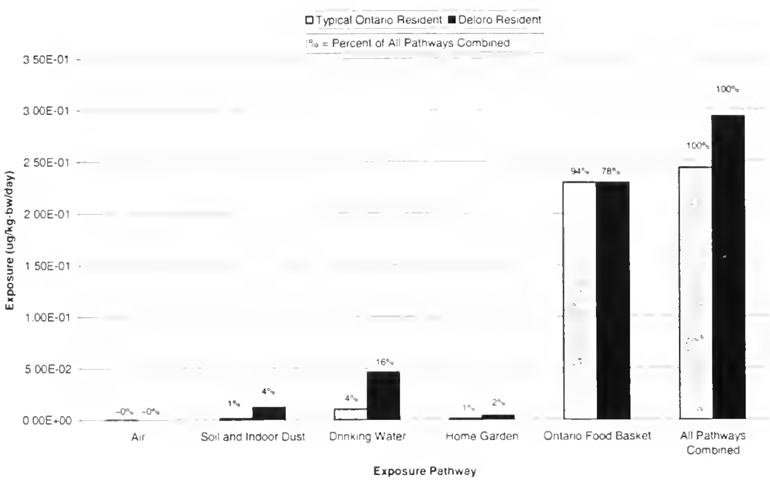
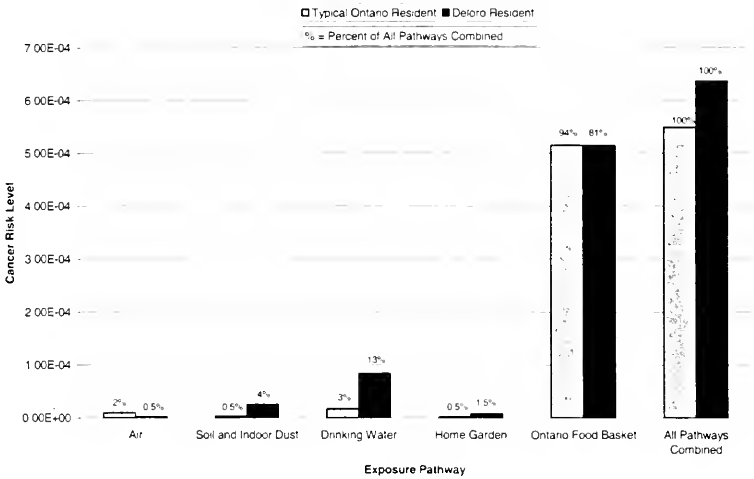


FIGURE ES-3
CONTRIBUTION OF VARIOUS PATHWAYS TO ADULT RECEPTOR EXPOSURE TO ARSENIC (PROBABILISTIC MEAN)



Predicted cancer and non-cancer risk levels were only slightly higher for Deloro residents than for persons living elsewhere in Ontario. For example, it was estimated that roughly 80 percent of lifetime exposure to arsenic in Deloro is from the normal Ontario food basket, as compared to roughly 4 percent for soil and indoor dust combined. The relative contribution of specific pathways to total lifetime risk (e.g. backyard vegetables, diet, soil) is shown in Figure ES-4. The combined risk from soil, indoor dust and home garden produce is one tenth that of the regular Ontario food basket. Furthermore, the levels of risk for each of the soil and indoor dust and backyard vegetable pathways were found to be in the range that is considered negligible.

FIGURE ES-4
CONTRIBUTION OF VARIOUS EXPOSURE PATHWAYS TO LIFETIME RISK FROM EXPOSURE TO ARSENIC (PROBABILISTIC MEAN)



If all soils in Deloro were replaced with background soils, overall risks would be reduced by only 2 to 4 percent.

Deloro residents would not experience risks from exposure to lead that were significantly greater than typical Ontario residents. No adverse health effects would be expected to occur at the levels of lead found in the village, as these levels were not unusually high.

Levels of cobalt and silver in the Village of Deloro are not high enough to result in any measurable health risk. Risks from exposure to nickel in Deloro were comparable to typical Ontario residents.

Radiological

The radiological doses and lifetime risks predicted for current residents of the Village of Deloro were comparable to and within the range of doses and risks for typical Ontario residents from natural background radioactivity.

The major contributor to lifetime risk was radon, which accounted for about 70 percent of the average lifetime risk for a Deloro resident. Gamma radiation and water ingestion accounted for about 17 percent and about 11 percent of the average lifetime risk, respectively. Risk from inhalation of airborne dust and ingestion of soil, dust, and garden produce accounted for less than 1 percent of the total lifetime risk. The estimated risk from water ingestion is highly uncertain and in all likelihood is overestimated, since the risk calculation is driven by the laboratory detection limits (the water concentrations were below the detection limit). There is no significant radioactivity in the village, and the water is safe.

Although the estimated doses and resulting radiological risks to residents of the village are comparable to typical background doses and risks, there is still an indication of higher risks from gamma radiation closer to the mine site. Higher indoor radon levels may be of natural origin.

Combined Metal and Radiological Risks

The 95th percentile lifetime cancer risk level (CRL) due to arsenic exposure for a resident considering the whole town on average (Deloro alone) who consumes home-garden produce (all cancers combined) was 1.82 E-04. The lung cancer risk proportion of this total cancer risk was 7.14E-07.

The only known health impact associated with exposures to elevated levels of airborne radon progeny is lung cancer. Therefore, the estimated lifetime risks associated with radon progeny exposures in Deloro can be considered attributable to the risk of lung cancer. For gamma radiation, which irradiates the whole body, the potential detriment and risk relates to all types of cancer. Based on these results, the contribution of arsenic to lung cancer risk (95th percentile 7.14 E-07) is insignificant compared to the risk obtained from radon progeny exposure (95th percentile of 1.3 E-02). The total cancer risk is comparable to the typical background risk.

Metal and Radiological Risk Results for a Population the Size of Deloro

The estimated radiological and chemical risks to the 140 people of Deloro are not large enough to be measurable relative to the background risks. Therefore, there will not be a statistically significant increase in cancer incidence within Deloro over background cancer risks. Deloro is a population of 140 people, therefore theoretically for Deloro this would translate into 0.0023 additional skin cancer cases per year based on the probabilistic 99th percentile exposure to arsenic over a lifetime, and 0.026 additional lung cancer cases per year based on the probabilistic 95th percentile exposure to radon over a lifetime. Because these are fractional cases per year, observing an incident in Deloro is unlikely.

Cancer Incidence and Mortality in Deloro and Hastings County

The Hastings County Health Unit undertook an assessment of cancer incidence and mortality rates in Deloro and the population of the surrounding area (including downstream along the Moira River) from 1980 to 1995. Reviews were conducted for the following 12 cancer sites: lip; oral cavity and pharynx; stomach; colorectal; pancreas; nasal cavity; lung; breast; cervix; prostate; bladder; kidney; leukemia; and all sites. The site-specific cancers were selected because they had been identified in the literature as being potentially associated with the contaminants present at the Deloro Mine Site or because they were relatively common cancers that could provide useful comparisons. Skin cancer was excluded because diagnosis and reporting of non-melanoma skin cancer is incomplete and unreliable. Cancer cases for Deloro were grouped with other municipalities because there were too few cases in Deloro to release the information without violating guidelines for confidentiality or to calculate reliable statistics.

The study found significantly high and low standardized incidence and mortality rates for at least some cancers in every area within Hastings and Prince Edward Counties Health Unit. The following comments focus on significant findings for Deloro and surrounding areas:

- With respect to mortality, summarized standardized mortality ratios were high for lung cancer and leukemia in males compared to Ontario, but not when compared to other areas in Hastings County. There was no evidence of a statistically significant trend over time, although leukemia mortality rates appeared to decrease from the early 1980s to the mid-1990s. Females had significantly low summarized standardized mortality ratios for leukemia and stomach cancer when compared to the province. The fact that the total number of observed leukemia deaths was almost exactly what would be expected suggests the cases were distributed unevenly between the sexes by chance.
- For Deloro and surrounding area, standardized incidence ratios were high for lung cancer in males compared to Ontario, but not when compared to other geographic areas in Hastings County. There was no evidence of a trend over time. Females had significantly low summarized standardized incidence ratios for stomach cancer and colorectal cancer.
- For the cancers studied, no incidence or mortality rate was high enough to suggest further, more detailed analysis was warranted for either males or females.

Conservative Elements of the Study

Predictions of exposure and risk are only estimates and these estimates do not necessarily reflect any one person's actual exposure of risk. In fact, exposure will vary among people because of their different activities, the amount of time in contact with a substance, and age (children tend to have higher exposures because of their smaller body weight). As a precaution, in these studies various assumptions are made that tend to overestimate risk to a considerable degree.

These conservative assumptions include, for example:

- Use of the U.S. Environmental Protection Agency (EPA) toxicity factors and cancer slopes for calculating risk. These factors are considered by the U.S. EPA to be over-estimating the risks. The expert peer review agreed that the risk values would be overestimated. There are large uncertainty or safety factors placed in these toxicity factors.
- In many cases, environmental concentrations were not detectable. However, rather than assume they are not there, the study assumes that they are present at half the detection limit and bases the risk calculations on this. Using a more sensitive method of analysis would likely demonstrate lower risks than were calculated.
- Although household swipe samples detected very little contamination in dust, the study team recognized that this was not an indication that contaminants were not in homes but rather that contaminants were not in the dusts that persons would have the most direct contact with. Vacuum samples were not collected because these methods tend to underestimate risk. Instead the study assumed that indoor dust was contaminated in relationship to the levels outside the house, and risk estimates were based on that assumption.
- Backyard gardens sampled did not have the highest arsenic in soil levels. Therefore the risk assessment modelled what levels in fruits and vegetables might be in other areas of the village. In other words, theoretical garden conditions were modelled that were not evident in the village.
- Risk estimates are based on a lifetime of exposure over 70 years. In most cases persons do not live in one area over their whole lifetime. As such, for many people this is another factor that overestimates the risk calculations.

In the study chemical concentrations were assumed to remain unchanged in the future. This overestimates risk, since with the closure of the mine site metals in the village will decrease over time, albeit slowly.

Overall Conclusions

The following overall conclusions are made based on this study.

1. Sampling indicates that there are elevated levels of arsenic, cobalt, and lead in soils and above-background levels of other contaminants including radon and gamma radiation in some localized areas of the village.
2. The results of the risk study strongly indicate that there are no unsafe exposures or adverse health effects associated with the contamination in the village. Although the levels of arsenic and other metals were found to be elevated due to the past century of industrial activity at the mine, the analysis and expert advice supports the conclusion that under the range of conditions considered, it is safe to reside in the village and its homes.[2]

[2] Safe in this context means negligible risk. Safe is arrived at based on comparison to what is typical (i.e. there is no meaningful difference).

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Acknowledgements

A scientific project of this magnitude and complexity cannot be undertaken without the dedication, expertise and cooperation of a large number of people. I would particularly like to thank my colleagues in the Ministry of the Environment (MOE) for their outstanding efforts in support of this work. They are, from the Eastern Region Office, Jim Ritter, Brian Ward, Jim Mahoney, Barbara Theman, Heather Hawthorne, John Tooley, and Bruce Hancock; from the Standards Development Branch, Murray Dixon, Dave McLaughlin, Adam Socha, and Jim Smith; and from the Laboratory Services Branch, Regina Pearce, Julie Uzonyi, Jim Howden, and Chris Gibson. Laboratory analysis for radionuclides in soil and vegetation was performed by Ken Gilmer and his colleagues at the Radiation Protection Service of the Ontario Ministry of Labour.

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Last, but certainly not least, the partipation in the study by the residents of Deloro, Ontario was very high. In addition, volunteers from the neighbouring community of Havelock, Ontario gave of their time to participate in the study. The study would not have been possible without their participation and cooperation.

Again, my thanks to all those on the team who contributed.

Scott W. Fleming
Chair, Deloro Health Risk Study Project
Ontario Ministry of the Environment

1. Introduction and Background

The former Deloro Mine/Refinery in Deloro, Ontario, is located in Hastings County, approximately 8 km east of Marmora and 45 km north of Belleville (see Figure 1-1). Situated where the Canadian Shield intersects with the Great Lakes Lowlands, the area is rich in mineral deposits. Gold was mined in the area, resulting in the storage and handling of hazardous chemicals. Arsenic was a by-product of the mining operation. Subsequent smelting and refining operations were also highly harmful to the surrounding environment. Since the 1960s, the Ontario Ministry of the Environment (MOE) has been taking steps to assess and remediate the pollution and its effects on the mine/refinery site and on neighbouring properties, including the Village of Deloro. The Deloro Village Environmental Health Risk Study Technical Steering Committee included senior scientists from the MOE and the Ministry of Labour, and medical doctors from the Hastings and Prince Edward Counties Health Unit, the Ministry of Health, and the Toronto Hospital for Sick Children. See Appendix A for biosketches of the committee members.

In June 1998, the committee developed a work plan for an environmental health risk assessment for the Village of Deloro to help define the boundaries of contamination resulting from the former mining and refining activities and to look at potential health effects on the community (see Appendix B, Draft Terms of Reference for the Deloro Environmental Village Health Risk Study). A committee of Deloro residents also provided input on the study design and follow-up. The specific objectives of the study were to determine, through environmental sampling of various media (soil, vegetables, air, dust, and water), if contaminants from the former Deloro Mine Site were present at significant concentrations in the community and to assess the likelihood of health effects from exposure to these contaminants through biological monitoring and health risk assessments.

In August 1998, CH2M Gore and Storrie Limited (CG&S) was retained by the MOE to provide overall project management and coordination of this study. With CG&S acting as the prime consultant, a number of expert consultants were retained to assist with different aspects of the study. The Phytotoxicology Section of the Standards Development Branch of the MOE provided expertise and staff for a phytotoxicological study involving soil, garden soil, and garden vegetable sampling. CG&S performed some of the environmental sampling of outdoor dust and water from private wells. LEX Scientific Inc. (LEX) was subcontracted to perform sampling of indoor and outdoor air and settled dust. CANVIRO Analytical Laboratories Ltd. and Becquerel Laboratories Inc. were retained to analyze samples for metals and radionuclides, respectively. Goss Gilroy Inc. (GGI) was subcontracted to perform the biological monitoring, to develop and administer a risk factor questionnaire, and to analyze the resulting data. Maxxam Analytics Inc. was retained to analyze arsenic in urine. SENES Consultants Ltd. (SENES) was subcontracted to perform gamma radiation and radon measurements, and to undertake an exposure assessment for radionuclides. CANTOX Environmental (CANTOX) was subcontracted to undertake the exposure assessment for arsenic and

other metals. See Appendix A for profiles of the consulting team. Results from each aspect of the study are included with this report as separate volumes.

This report, the Deloro Village Environmental Health Risk Study – Overall Technical Summary, comprises Volume I of the Deloro Village Environmental Health Risk Study report, and summarizes the activities performed as outlined in CG&S's proposal dated August 18, 1998, and addendums dated August 19 and 24, 1998. A plain-language report is included as Volume II. Volumes III to VIII contain stand-alone reports prepared by the expert consultants for each major aspect of the study.

Definitions

Due to the highly technical nature of this study, the reader may be unfamiliar with some of the terms used. This section defines a few of the more commonly used terms in this summary report. Appendix C contains a more comprehensive glossary of terms used throughout the study report.

Risk assessment is aimed at determining what the magnitude of exposures may be through various pathways for different subgroups and whether or not adverse or undesirable effects from such chemicals would be expected.

Health risk study is the qualitative and quantitative estimation of the magnitude, frequency, duration, and route of exposure to a particular physical, chemical, or biological disturbance in the environment. It delineates major pathways.

Multimedia exposure assessment is an approach to risk assessment looking at total exposure to a substance through a number of possible pathways, such as air, soil, drinking water, and food. To evaluate the health consequences of exposure to a contaminant through a particular pathway or source, it is necessary to understand the total exposure picture from all routes.

Deterministic modelling involves the selection of single values, or point estimates, for each of the parameters used in the calculations to arrive at single estimates of risk for the receptors under consideration. This type of modelling tends to maximize the estimated risks as values are chosen from the possible range of values. This usually gives a "worst-case" scenario and may be considered useful to determine the potential relative importance of various exposure pathways and contaminants.

Probabilistic modelling tries to capture the effect of variability in location, environmental concentrations, and other factors. Input parameters used are distributions instead of single values, so as to reflect natural variability and uncertainty within a particular category or parameter.

Risk often is defined as the probability or likelihood that an adverse outcome will be caused by an action or condition. Actions and conditions of concern usually are associated with the exposure to a chemical or physical agent such as noise, heat, or radiation.

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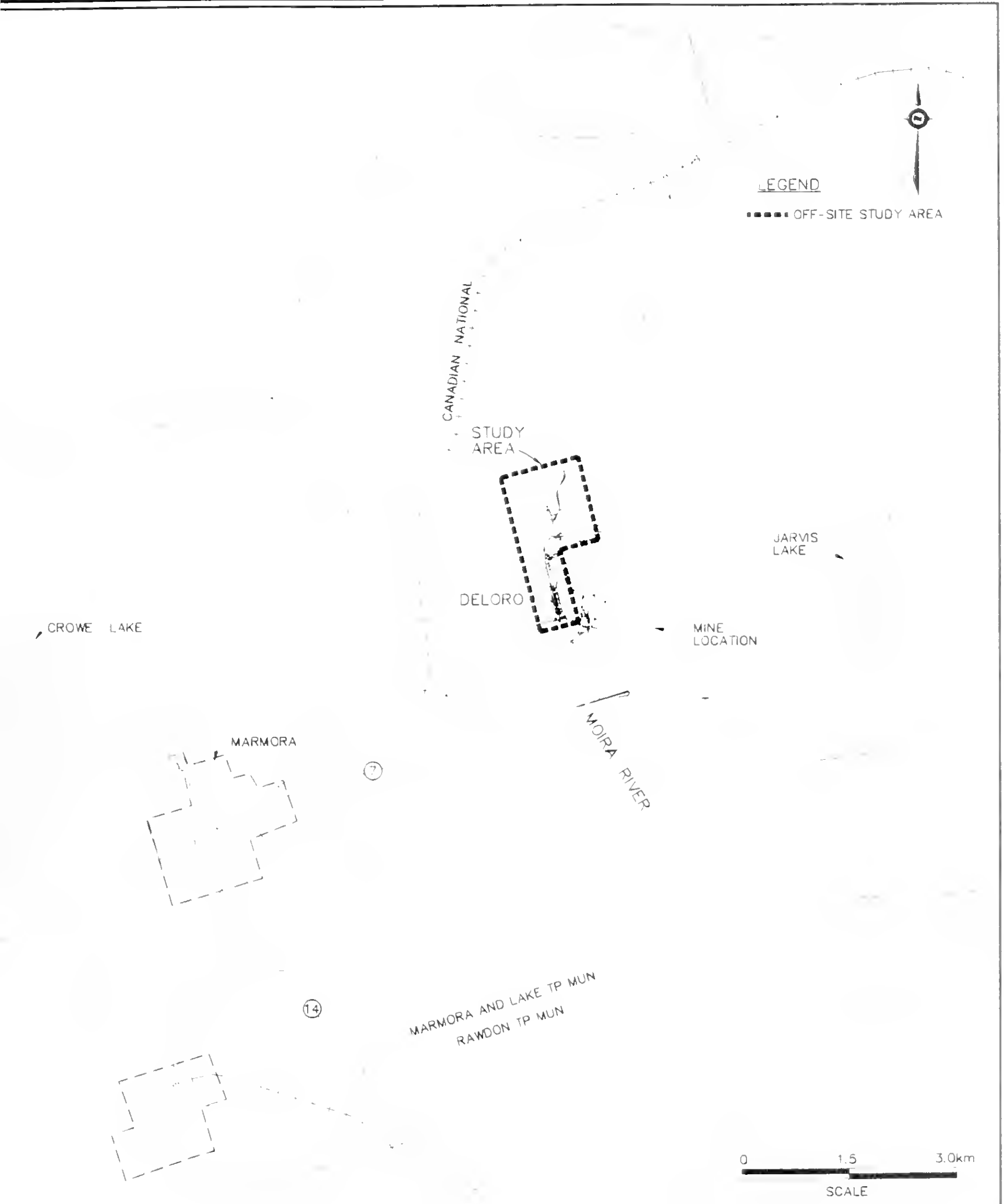

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Figure 1-1

Deloro Village
Environmental Health Risk Study Area

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Physical Characteristics of the Area

Location

The Village of Deloro is located along the banks of the Moira River, 8 km east of the Marmora Township office and 45 km north of Belleville. The village consists of approximately 65 residences housing 140 people. The former mine/refinery site is approximately 242 ha in area and is located immediately adjacent to the east of the village. Entrance to the village is via Deloro Road, which is accessed from Highway No. 7 approximately 4 km east of Marmora. Other population centres in the area of the Village of Deloro are the Villages of Marmora (pop. 1,700) and Madoc (pop. 1,400) located approximately 5 km southwest and 10 km east of the site, respectively.

Geology

There is limited information on the geology of the village area but it is assumed that it is similar to the mine property. Deloro is located at the contact between Precambrian basement rocks and overlying Paleozoic sedimentary rocks. Bedrock is thought to run under the village and becomes exposed primarily at the north end of the mine site. The natural overburden consists primarily of silty clay with minor amounts of silty sand and peat. Precambrian metasedimentary and metavolcanic rock forms the bedrock under most of the area. The village is underlain by Paleozoic limestone and shale, which extends onto the mine site property.

Topography

The area of study is located near the geologic contact between Precambrian shield strata to the east and relatively flat-lying Paleozoic limestone, which underlies most of the village. The surface of the Precambrian bedrock is very irregular and reflects weathering processes during early Paleozoic times prior to the deposition of the limestone strata that now covers much of the area. The irregular bedrock surface often protrudes through the overburden, forming prominent bedrock knobs over much of the site. In general, the ground surface slopes to the south and to the east toward the Moira River. Elevations along the eastern boundary of the village are approximately 210 metres above sea level (masl).

Hydrogeology/Hydrology

There is limited information on the hydrogeology and hydrology of the Village of Deloro, but it is assumed to be similar to that of the mine site. Groundwater flows beneath the surface through overburden, bedrock, and/or a combination of both. In general, the groundwater flow direction is believed to be easterly and southeasterly toward the Moira River. This indicates that any contaminated water originating from the mine site would not flow towards the Village of Deloro. In the overburden, groundwater flows are concentrated along more permeable material usually lying directly on the bedrock surface. In the bedrock, groundwater flows occur primarily along fractures, bedding planes, and similar geological features. Fracture frequency and aperture generally decrease with depth and, therefore, groundwater flow through the bedrock is expected to be greater in the shallow bedrock. Bedrock flow patterns are influenced by zones of higher hydraulic conductivity associated with natural faulting

and/or folding. The Moira River watershed, which includes the Village of Deloro, comprises 2,750 km^2. Flows from this watershed are discharged into the Bay of Quinte on the northern shore of Lake Ontario.

Climate

The Deloro area and the surrounding region receive an average yearly precipitation of 889 mm (Environment Canada, 1990). Maximum precipitation usually occurs in September, with approximately 80 to 100 mm of rain. The spring to fall average mean temperature is 16.9°C, and the winter mean temperature is –7.4°C. The daily minimum average temperature for January and February is –13.4°C and the daily maximum high average is 25.3°C for June to August, for an annual range of approximately 38.7°C. The record high was recorded in summer 1988, when temperatures exceeded 40.6°C over a 7-day period. The record low for the area is –40°C. November to March winds prevail from the west, and spring and summer winds prevail from the southwest. This pattern indicates that the predominant wind direction would act to restrict contaminated blowing dust from migrating from the former mine site to the village.

History of the Site

Mining and Extracting Operations

During the mid-1800s, gold was found in the vicinity of Deloro in quartz veins associated with mispickel ores, which required a smelting process that could eliminate associated arsenic compounds. By 1871, seven gold sites in the Moira River valley were being worked, with 25 shallow shafts at Deloro alone. The Canada Consolidated Gold Mining Company acquired the Deloro site in 1880. In 1882, 100 men were working onsite. A chlorination process was used to recover the arsenic as well as the gold. In 1884, a new process for the recovery of gold from the tailings was discovered. The tailings were applied to an oscillating table containing mercury, sodium amalgam, nitrate of mercury, and copper filings. Between 1885 and 1891, 645 tons of refined arsenic oxide were produced. In 1896, the Sulman-Teed process was used to increase the recovery of gold and also to produce a white arsenic that became a valuable by-product. The Sulman-Teed process consisted of gold extraction by leaching the finely ground ore with a solution of potassium cyanide and a small quantity of a "haloid" salt of cyanogen-bromide. The gold was then precipitated using metallic zinc.

Smelting and Refining Operations

The Deloro Mining and Reduction Company was incorporated in 1907. Over the next 12 years a residential community developed next to the site consisting of private homes built of wooden clapboard or concrete block, a community hall, and a school. Experiments on arsenic extraction from silver and cobalt ores were undertaken in Deloro. In 1912, a process for producing cobalt metal was discovered and became the focus for Deloro smelting. This process, along with the silver extraction, the separation and refining of other metals, the development of uses for cobalt metals, and the continued need for arsenic, ensured Deloro's success for a period of time. The existing smelter for

gold at Deloro was used for ores from Cobalt, Ontario. The processes included separation of silver and the refining of other metals including cobalt, nickel, and arsenic.

From 1907 to 1916 there was significant development, including the upgrade of existing buildings and the addition of several new buildings and plants for processing silver. The facility had the capacity for processing 40 to 60 tons of silver ores per day, using cyaniding, smelting, roasting, and chlorination processes. A new cobalt oxide plant in steel, concrete, and brick was added in 1910. The plant had the daily capacity for 450 to 900 kg of cobalt oxide. There was also a large filtering plant for water coming into the oxide plant. The old arsenic plant continued operation until at least the First World War. Crude arsenic was refined in three coke-fired chambers and the fumes were collected through brick and steel cooling chambers, where they condensed into a powder. The powder was then taken into an arsenic packing house (bag house) and packed into barrels. A new bag house was added in 1917, and an automatic bag house was added in 1924. In 1915, Deloro's capacity was 400 to 500 tons of ore per month. It was producing 20,000 to 30,000 kg of cobalt oxide and metal; 7,000 to 9,000 kg of nickel oxides and metal; and 14,000 kg of silver.

In 1916, a new process was developed that successfully treated lower grades of silver ores by means of a flotation process using oil and water. A plant to manufacture aluminum dust was also installed for the processing of silver. A process was also developed to create cobalt oxides from the residues of ore after silver production, and Deloro became the world's first commercial producer of cobalt metal. Stellite (an alloy of 55 percent cobalt, 28 percent chromium, and 14 percent tungsten) was subsequently produced at Deloro. The Deloro Chemical Company (1920–28) established insecticide and salts plants north of the smelting operations. The plant refined cobalt salts such as sulphate, acetate, nitrate, chloride, hydrate, and carbonate, as well as lead, Paris Green, and calcium arsenate. Arsenic trioxide continued to be produced and sold after the company ceased operations. A 1935 newspaper article described the different processes and products from Deloro as including smelting and refining of silver, arsenic, cobalt, nickel, lead, bismuth, and copper, with some 3,000 tons of silver shipped since production started and 36,000 tons of arsenic since 1907.

Ore from Cobalt, Ontario, had been stockpiled at Deloro during the Depression, but it was using other suppliers of cobalt ore. Ore was received from the Eldorado refinery in Port Hope between 1929 and 1939.

Germany's invasion of Belgium during the Second World War re-routed African ores to Deloro. Demand for cobalt in the United States raised prices and caused the waste dumps in the Cobalt field to be picked over. The U.S. government stored 4,000 tons of cobalt at Deloro during the war. In 1940, a research lab for metallography and for spectrographic and physical testing was built. A chemical lab and sample room was built nearby. Here, a smelting process for uranium from the Eldorado plant in Port Hope and a hot wax process for precision casting were developed. After the Second World War production dropped, but revived again during the Korean War and for Cold War defences in the 1950s.

In 1951, the old silver plant was torn down and a new building—a primary treatment plant with a high trestle, ball mills, and new crushing system—was constructed in its place. The arsenic bag house was replaced and a new castings building was erected. The

main sections included the crushing, grinding, roasting, and smelting departments; the chemical sections; and the machine tool and casting divisions. The final marketable products were consistent with previous years: silver, refined arsenic, cobalt oxides and salts, cobalt metals and powder, nickel oxide, and copper residues.

In 1955, the whole stellite and precision casting section was moved to Belleville. In the late 1950s, insecticides based on arsenic trioxides were replaced by organic pesticides, causing tons of arsenic to be stockpiled onsite. Deloro was forced to cease cobalt processing. The plant ultimately closed in 1961.

Contamination of the Mine/Refinery Site

Throughout the site's history, arsenic and gold were found as natural compounds in the area, but the operation's recovery and subsequent production and use of chemicals for processing led to massive contamination of the area. Furthermore, by-products of the production of oxides, stellite, arsenic, and insecticides are also found throughout the area, along with residues from lab experiments. It is assumed that the hazardous chemicals and industrial by-products were stored and disposed of around the mine refinery site, including the radioactive wastes from Eldorado Nuclear and the calcium arsenate precipitated from the arsenic trioxide. Throughout its history, the mine/refinery site became contaminated from arsenic compounds, caustic soda calcium arsenate, crude arsenic, ferric hydroxide tailings, slag, gold mine tailings, lab wastes, and chemical waste dumps.

MOE Involvement and Cleanup

After the closure of the mine site in 1961, most of the buildings were demolished. In the years following this, the Ontario government undertook several remedial actions. Through the Ontario Water Resources Commission, a groundwater investigation program was put in place to study the problem of arsenic contamination entering the Moira River. This investigation led to the implementation of a groundwater monitoring network that revealed areas of concern for the site, which in turn led to the construction of sewage works in 1966. Further action was taken by diverting the creek on the western side of the property to prevent further deposition of arsenic in the river; a plan to cover areas of calcium arsenite with slag; and future burial of the poison pond and underdraining the area. In 1970, Director's Orders placed on the site enforced the completion of the underdrain system; a repair of the tailings dam; upgrades in the chemical treatment system; surveys to define other arsenic sources; and an investigation into the stabilization of the red mud (tailings) area. 1973 saw the construction of a treatment plant and equalization lagoon for waste materials. The government's vigilance into the review of the Deloro area did not stop, as regular monitoring programs on the Moira River continued to be conducted during 1974. These studies showed that the water quality of the river was still deteriorating. At the same time, studies carried out on the soil and vegetation around the property showed heavy contamination with arsenic and that further improvements of the treatment systems were needed. The Ministry initiated another investigation outlining numerous sources of arsenic contamination around the site in 1976, and a Control Order under the Environmental Protection Act of Ontario was issued in 1978 to correct the problems. MOE assumed operation of the treatment facility on April 2, 1979, when the owners declared themselves unable to support the costs of the required cleanup. The Ministry continued to make improvements to the

facilities and the site, but recognized that additional improvements would still be required. As of the end of 1987, the MOE had spent $3.5-million to $4-million on pollution treatment and site rehabilitation. The work included demolition of unsafe structures, search for and stabilization of mine shafts, erection of a pump in the Tuttle Shaft, and construction of a concrete wall to prevent surface and below-surface runoff. New facilities included a treatment plant handling 120 gallons per minute; five pumping stations; an equalization pond; a new catch basin; and a new lagoon for drying sludge. The red mud area is completely covered by 0.5 m of crushed limestone and has a stabilizing dam surrounding it. Monitoring is provided year-round, and contamination is being minimized. There has been much study and preparation for the cleanup and closure of different areas of the mine, including the Tailings Area, the Young's Creek Area, and the Industrial Area. Site preparation work will commence in the fall of 1999 to position the project for major construction in the year 2000. A risk assessment study of the Moira River water use is being done separately from this report.

Lead-up to Initiation of the Study and Development of the Terms of Reference

There was limited previous work done in the Village of Deloro. In 1982 one residential indoor air sample and a few air outdoor air samples were collected near the treatment plant. A 1996 phytotoxicology study compared soil and vegetation data collected in 1986–87 to existing soil cleanup guidelines. These studies concluded that the soil in Deloro exceeded provincial guidelines for arsenic and cobalt, and was marginally above Ontario background levels for lead, nickel, and silver. Municipal drinking water was sampled for a wide range of parameters in May 1994 and again in April 1998. The drinking water quality was within Ontario Drinking Water Objectives (ODWO). There have been historical concerns regarding the presence of radon gas and gamma radiation in the village. During the spring and fall of 1976, radon progeny measurements in indoor air (grab samples) were taken in 68 homes in Deloro. The mean radon progeny concentration was reported to be 6 mWL (milli-working level), and the standard deviation was 3.3 mWL (Knight and Makepeace, 1980).

Based on the limited amount of information, a screening-level risk assessment was performed by the MOE in 1998. The MOE toxicological staff at the Standards Development Branch reviewed the analytical results of the soil sampling surveys conducted in and around the Village of Deloro. The possible health significance of elevated levels of arsenic was examined, and it was concluded that there was insufficient information on which to base meaningful interpretation of health effects and risk. It was recommended that a more comprehensive evaluation of exposure and potential risk to residents be undertaken.

Summary of Previous Investigations in the Village of Deloro

Ministry of Labour (MOL) Radon Survey (1986)

In 1986, a radiation survey of the MOE Arsenic Treatment Plant at Deloro and environs was conducted. The survey included measurements of radon gas and radon daughter concentrations within buildings, and measurements of gamma radiation levels throughout the site. Radon and radon daughter measurements were all within the range of

normal background levels. Gamma radiation exposure levels measured on the property indicated the necessity for some precautions to be taken by personnel when working in certain areas. The whole site had an elevated background of approximately 50 µR/h and localized areas where gamma exposure rates of up to 3,000 µR/h were observed. The recommended maximum non-radiation worker toxicological criterion is 500 mR per year, which corresponds to an occupational exposure rate of 250 µR/h for 2,000 hours. The areas of concern to the Village of Deloro were located near the west gate to the mine site just west of the new treatment plant and south of the equalization lagoon.

MOE Phytotoxicology Report (1998)

In 1998, the MOE conducted a phytotoxicology study that compared data collected in 1986–87 to the most recent (1994) MOE soil cleanup criteria. The study revealed the soil and vegetation in the Deloro Smelter and Tailings Area and some surrounding regions to be contaminated with a number of chemical elements that were known to be associated with past industrial activities. Although the highest concentrations were in the Mining Area itself, there was evidence to suggest offsite contamination, including in and around the Village of Deloro. Based on a limited number of samples, soil in the Village of Deloro was determined to be significantly contaminated with arsenic and cobalt, and marginally contaminated with nickel, lead, and silver. Arsenic, cobalt, molybdenum, and silver are considered to be naturally elevated in background soils. It was determined that of the 12 elements tested, only cobalt and iron were consistently associated with blowing dust. Arsenic, cobalt, copper, and nickel concentrations were consistently elevated in the areas where the soil was similarly contaminated. Although plant:soil chemical relationships were not directly proportional, it was apparent that elevated foliar concentrations of these elements were related to uptake from the contaminated soil. Based on produce collected from village gardens in 1986 and controlled-environment bioassays conducted in 1987, the concentrations of arsenic in edible vegetable produce grown in arsenic-contaminated soil from the Village of Deloro did not exceed the former federal government arsenic food guideline.

Project Objectives

The June 1998 Terms of Reference subdivided the project into a series of seven major components that were designed to address the overall project objectives. Individual components were assigned to selected consultants that could provide the highest quality relevant expertise. The overall study objectives, as specified in the Terms of Reference, are summarized as follows:

1. To determine if there are elevated levels of contaminants from the former Deloro Mine Site present in the community in various environmental media (soils, indoor and outdoor dusts, indoor and outdoor air, drinking water, and backyard vegetables).

2. To quantify the potential exposure of community residents through: (i) deterministic and, as specified, probabilistic exposure modelling, and (ii) biological monitoring of urinary arsenic in community residents together with a risk factor questionnaire administration and analysis.

3. To quantify the potential exposure from contaminated soils/dusts relative to other potential sources of exposure.

4. To quantify to what degree, if any, there may be increased health risks in the Deloro community and to characterize the possible significance of such risks based on exposure modelling and biological monitoring results and comparison of exposure and risk to typical Ontario exposure and risks.

5. To use the United States Environmental Protection Agency (USEPA) model for prediction of urinary arsenic levels to compare predicted versus observed values in the community.

6. To conduct a thorough information collection and provide a technical summary of applicable risk mitigation efforts and outcomes in other jurisdictions involving contamination of residential communities of arsenic associated with mine tailings or smelter operations.

Table 1.1 summarizes the major components of the study, where the results for that objective are found in this report, and in which volume the background information is located. Development of the major components (herein referred to as *tasks*) is discussed below.

Scope of Work/Study Design

The 1998 MOE phytotoxicological study suggested that soil in the Village of Deloro was significantly contaminated with arsenic and cobalt, and marginally contaminated with nickel, lead, and silver. In addition, there were historical concerns regarding the presence of gamma radiation and radon gas in the community.

A focus questionnaire administered to seven volunteer households indicated that there is no notable swimming activity in or fish consumption from the Moira River in the area of the mine site or the village. Two of the seven families indicated groundwater use for drinking and bathing. Generally, village air was characterized as very dusty. It was also indicated that some children do play directly on the mine site. These factors were considered in the design of the study. Emphasis was placed on soil, dusts, and drinking water, as there has been elimination of fish consumption and recreational swimming as pathways for data collection and exposure modelling. The original scope of work was developed by the Deloro Village Environmental Health Risk Study Technical Steering Committee. A committee of Deloro residents also provided input on the original study design. The resulting Terms of Reference for the Deloro Village Environmental Health Risk Study, dated June 1998, was reviewed by the selected consultant team prior to initiation of the study. The resulting study design was accomplished through an iterative process, whereby the consultant team would present suggestions and recommended changes to the Technical Steering Committee for approval. The following discussion outlines changes to the original Scope of Work with respect to environmental sampling of media.

TABLE 1.1
SUMMARY OF STUDY OBJECTIVES BY KEY TASKS

Task	Objectives	Location in Summary Report	Location of Background Information
I	Overall Project Management and Coordination Preparation of an overall technical summary of the study and findings Preparation of a plain language summary of the findings	NA NA	Volume I Volume II
II	Environmental Sampling, Analysis, and Reporting for Metals and Radionuclides Soil sampling and analysis of residences in the Village of Deloro; sampling of garden vegetables. Sampling and analysis of indoor and outdoor air and settled dust, and drinking water	Section 2	Volume III Volume IV
III	Environmental Sampling and Analysis for Radioactivity Gamma radiation survey of the entire village at medium density Radon measurements in air in each participating home	Section 2	Volume V
IV	Biological Monitoring, Risk Factor Questionnaires, and Analysis Design and administration of a risk factor interview questionnaire for arsenic exposure Identification of and sampling and measurement of speciated urinary arsenic in a suitable reference population Quantitative analysis of risk factors, testing specific hypotheses of associations between urinary arsenic and levels in environmental media	Section 3	Volume VI
V	Exposure Assessment and Health Risk Characterization for Arsenic and other Metals Conducting and documenting a summary review of the relevant literature regarding exposure to arsenic and other metals in the vicinity of mining/ smelting operations Multi-media exposure assessment providing quantitative deterministic estimates for exposure of groups Run USEPA model for urinary arsenic and a comparison to observed results	Section 5	Volume VII
VI	Exposure Assessment and Health Risk Characterization for Radionuclides, Gamma Radiation and Radon Calculation of total exposure via various pathways Incremental lifetime risk estimates Comparisons of exposure and risk to other areas of the province	Section 5	Volume VIII
	Epidemiological study	Section 4	In preparation by Others

- The number of outdoor sampling stations for dust and air was increased from 6 to 10, with two of the stations located outside the study area to act as comparison locations. The number of outdoor sampling stations for radon was increased from 6 to 11, with two of the stations located outside the study area to act as comparison locations.
- Soil, dust, air, and water sampling would also be analyzed for selected radionuclides within the uranium decay series.
- The indoor air sampling time was increased to allow for a higher method detection limit.

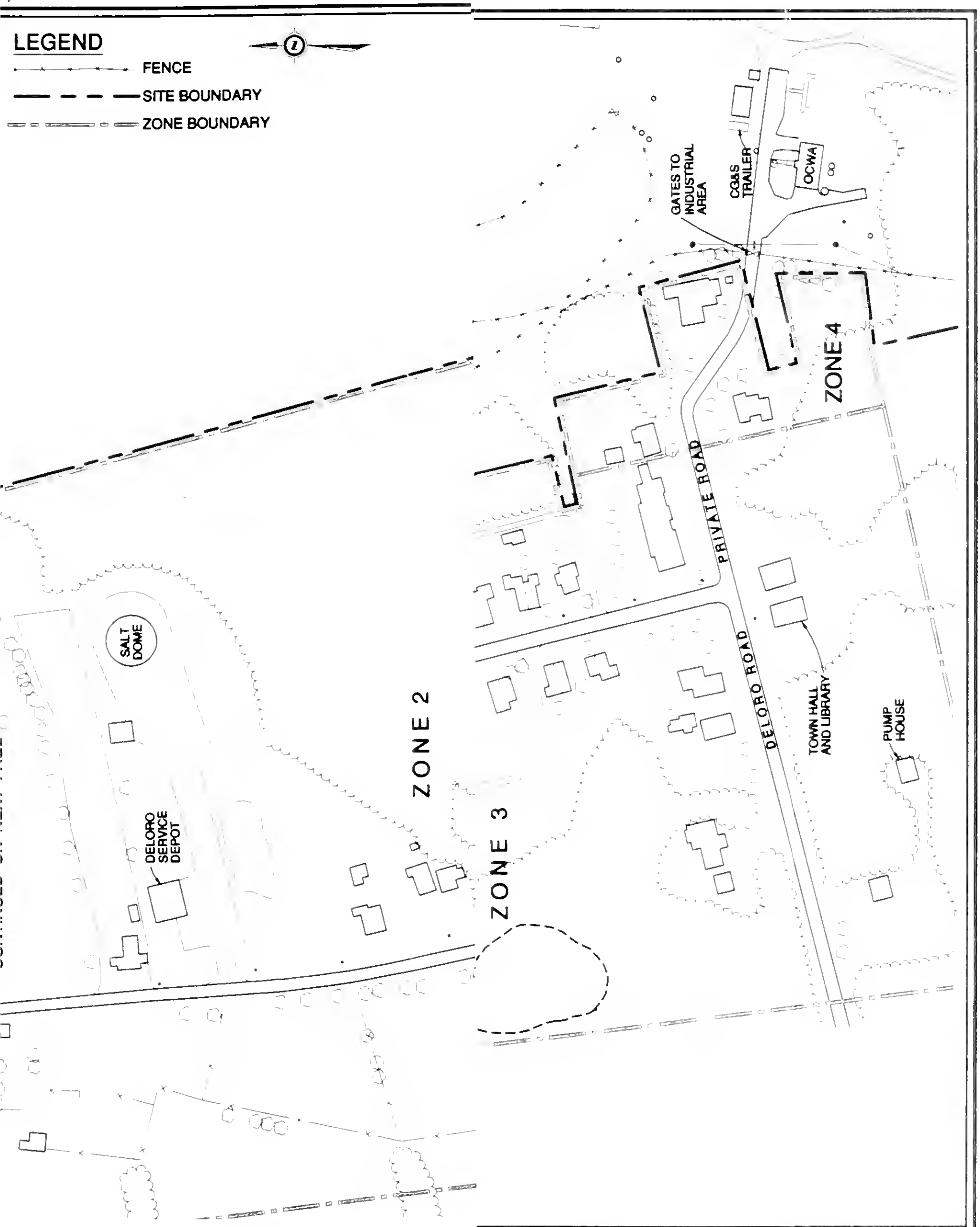
Havelock, Ontario, was chosen as the control community for the biological monitoring study, as Havelock was deemed to be of a sufficient distance from Deloro to not be affected by potential dust arising from the Deloro site, yet close enough to be willing to help a familiar neighbour by participating in the sample fieldwork and urine sampling. In total, a sample of 21 households with 54 residents (41 adults and 13 children) was selected from Havelock to match the age distribution of the Deloro residents.

The risk assessment team (CG&S, SENES, and CANTOX) met on a monthly basis to review data as they were collected and to develop the conceptual models. Significant changes to the original Scope of Work include:

- For the purpose of the exposure assessment, the Village of Deloro was theoretically divided into four areas or zones. (The zones are shown in Figures 1-2 and 1-3.) The zones were selected based on contaminant concentrations, residential density, use of private vs. municipal well water, and proximity to the mine. Zone 1 is the most northerly zone in Deloro; Zone 4 is adjacent to the mine site. Zone 1 refers to the media and site characterization data for residences north of 75 O'Brien Road (where radon "hits" were encountered, private well usage); Zone 2 refers to residences between 43 and 75 O'Brien Road (private well use); Zone 3 consists of the remaining study area and residences with the exception of those located on Private Road, or Zone 4 closest to the mine site.
- Based on the door-to-door survey conducted by CG&S as part of the program to invite residents to participate in the study, it was noted that approximately 40 percent of residents regularly go for walks on the mine site. As a result, the risk assessment team determined that a "trespasser scenario" should be incorporated into the risk assessment models for the offsite risk assessments.

Peer Review Process

The Ministry asked leading international experts from Canada and the United States to review the study reports and findings. This meticulous review was conducted to ensure that the findings were scientifically correct and to ensure that no important information or interpretation had been overlooked. Overall, peer reviewers were in concordance with the study design and findings. Specific peer review comments are included in the individual consultant technical reports. External peer reviewers are shown in Table 1.2. For more detailed information on external peer reviewers see Appendix A.



50 100m
SCALE

Figure 1-2

Village of Deloro
Environmental Health Risk Study
Zone Delineation Plan
(Zones 2 and 3)

F102

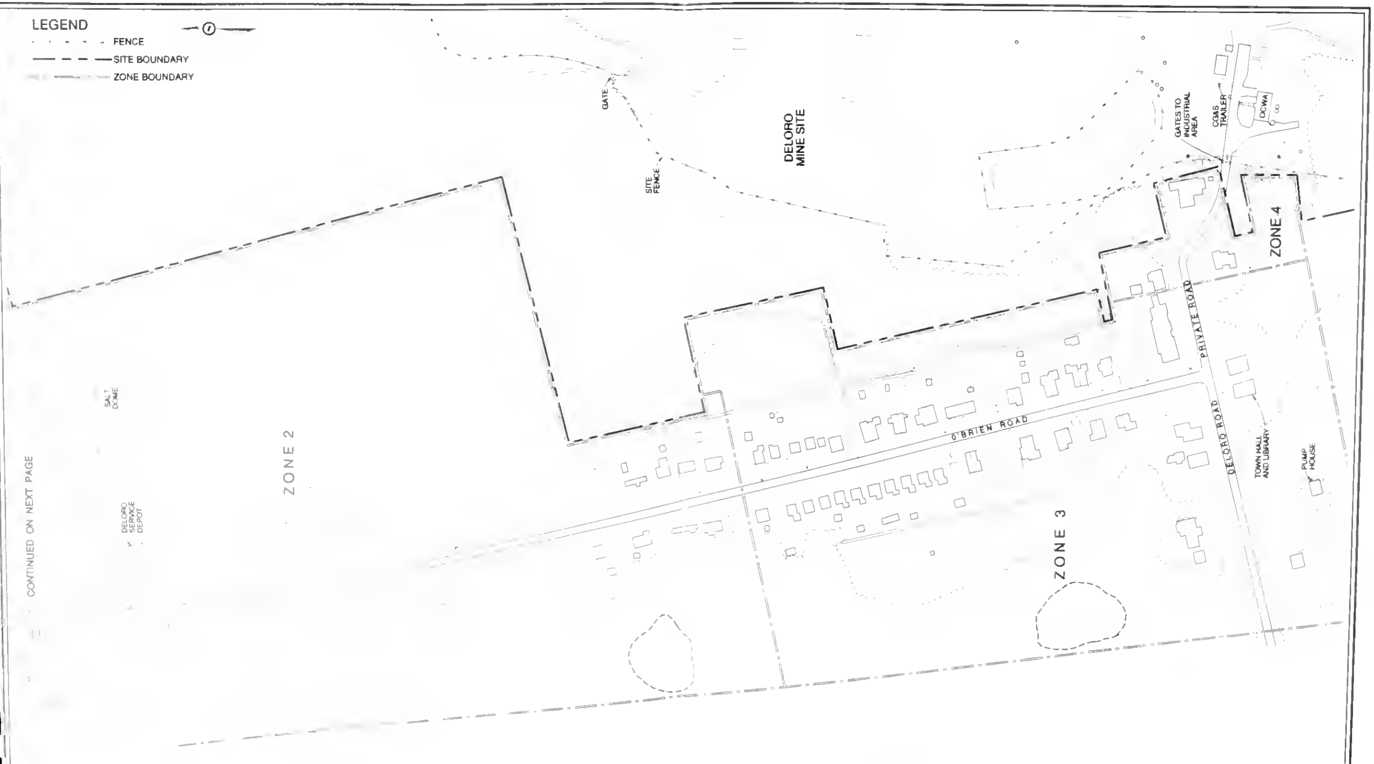


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Figure 1-2

Village of Deloro
Environmental Health Risk Study
Zone Delineation Plan
(Zones 2 and 3)

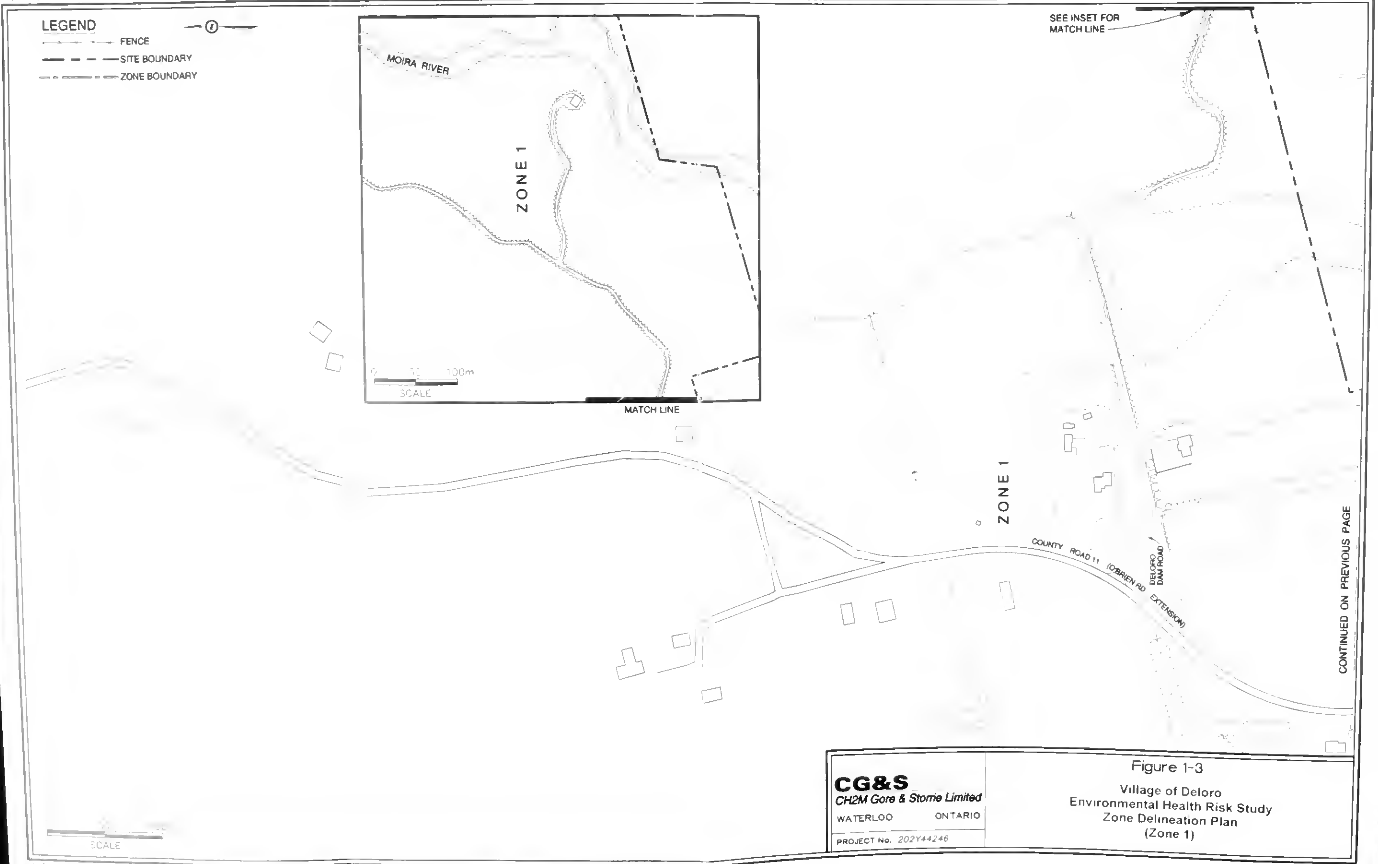

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Figure 1-3
Village of Deloro
Environmental Health Risk Study
Zone Delineation Plan
(Zone 1)

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Figure 1-3

Village of Deloro
Environmental Health Risk Study
Zone Delineation Plan
(Zone 1)

TABLE 1.2
EXTERNAL PEER REVIEWERS

Individual	Association	Expertise
Dr. Charles Abernathy	U.S. Environmental Protection Agency	Toxicologist- arsenic health effects and drinking water
Dr. Bliss Tracy	Health Canada	Radiation scientist -exposure and health effects of radiation
Dr. Willard Chappell	University of Colorado	Professor of physics - arsenic exposure and health effects
Dr. Chris Le	University of Alberta	Associate professor, public health,- arsenic exposure and urinary analysis
Dr. Buck Grisson	Centre for Disease Control, ATSDR	Toxicologist - arsenic exposure and risk assessment
Dr. Henry Caplan	University of Saskatchewan	Professor of physics - environmental radiation and risk
Mr. Mark Gardiner	Low Level Radioactive Management Office, Port Hope	Radiation sampling and remediation

Report Organization

This report is divided into seven sections. This introductory section includes a discussion of the project background and objectives, and outlines the scope of work. Section 2 summarizes the results of the activities included in Task II, Environmental Sampling, Analysis and Reporting for Metals and Radionuclides, and Task III, Environmental Sampling and Analysis for Radioactivity. Section 3 summarizes the results from Task IV, the Biological Monitoring and Risk Factor Questionnaire and Analysis, and Section 4 summarizes the epidemiology study completed by the Hastings and Prince Edward Counties Health Unit. Section 5 summarizes the risk assessments, including the information from the arsenic and metals exposure assessment and the radiation exposure assessment. Section 5 also addresses the issue of harmonized risk from both of these types of contaminants. Section 6 presents the conclusions and potential risk mitigation options. Section 7 lists references used in the preparation of this report.

The background documentation for each task is presented in the accompanying volumes. Each report is a complete volume unto itself, as prepared by the expert consultant. A brief overview of the contents is provided here.

Volume I – Overall Technical Summary Report, by CG&S

This report summarizes the results of the activities conducted as part of the Deloro Village Environmental Health Risk Study. CG&S compiled it as the main consultant. The report provides background to the issues at the site and potential risk mitigation options.

Volume II – Summary Report, by MOE

This report summarizes the Overall Technical Summary Report in non-technical language.

Volume III – 1998 Phytotoxicity Report, by the MOE

In spring 1998, the phytotoxicology section of the Standards Development Branch at the MOE took surface soil samples from residences, gardens, and public areas, and depth samples from selected areas. A study of seedlings planted in the gardens of volunteers was also conducted. This report summarizes the results of those activities.

Volume IV – Summary Report of Air, Settled Dust, and Drinking Water Sampling and Analysis Report by CG&S

CG&S performed environmental sampling for outdoor dust and drinking water. LEX Scientific Inc. was subcontracted for expertise in air and dust sampling and to perform sampling of indoor and outdoor air and settled dust. The results of LEX's sampling are included in this report with CG&S's results. CANVIRO Analytical Laboratories Ltd. and Becquerel Laboratories Inc. were retained to analyze samples for metals and radionuclides, respectively.

Volume V – The Results of Environmental Radiation Monitoring Conducted in Support of the Deloro Village Environmental Health Risk Assessment, by SENES Consultants Ltd.

SENES Consultants Ltd. was contracted for expertise in radiation studies. This report summarizes the results of the activities undertaken with respect to measurements of gamma radiation and radon gas in the area of the Village of Deloro.

Volume VI – Deloro Village Environmental Health Risk Study, by Goss Gilroy, Inc.

Goss Gilroy, Inc. was contracted to perform the biological monitoring and administer the risk factor questionnaire. Maxxam Analytics provided analyses of total and speciated arsenic in the urine samples. This report summarizes the findings of the data collection in Deloro and compares them to the findings for Havelock, the control community. The report also compares concentrations of arsenic in urine to concentrations of arsenic in other environmental media.

Volume VII – Exposure Assessment and Health Risk Characterization for Arsenic and Other Metals, by CANTOX Environmental, Inc.

As part of the risk assessment, CANTOX Environmental, Inc. was retained to provide a literature review regarding exposure to arsenic and other metals as well as an exposure assessment and health risk characterization. The assessment was performed in consultation with the Technical Steering Committee and the risk assessment team.

Volume VIII – Exposure Assessment and Health Risk Characterization for Radionuclides, Gamma Radiation, and Radon, by SENES Consultants, Ltd.

SENES Consultants, Ltd. performed the exposure assessment for radiation. The assessment was performed in consultation with the Technical Steering Committee and the risk assessment team.

2. Investigations Summary

The overall study objective related to environmental sampling, as specified in the Terms of Reference for the Deloro Village Environmental Health Risk Study, was to determine if there are elevated levels of contaminants from the former Deloro Mine Site present in the community in various environmental media (soils, backyard vegetables, indoor and outdoor dusts, indoor and outdoor air, and drinking water). Environmental sampling for soil and garden vegetables commenced in April 1998; the remainder of environmental media samples were collected from September through November of 1998. Participation in the environmental health risk study was voluntary.

Invitations to Deloro residents to participate in the biological monitoring component and environmental sampling for indoor air and dust, indoor and outdoor radon, gamma radiation, and drinking water) were issued on September 25, 1998, and continued throughout the duration of the field investigation phase of the study. Several attempts were made to contact residents at all of the homes in person, followed by phone calls and letters. Upon contact, residents who were willing to participate were asked a series of questions relating to their activity patterns and drinking water supply. All residents willing to participate and available during the sampling period were included in the study. The participation rate was excellent, at greater than 80 percent. The study area included the village proper, the area around the municipal salt dome, a residence immediately north of the mine site, and several residences north of Deloro Dam Road. (The study area is outlined on Figure 1-1.)

Environmental Sampling, Analysis, and Reporting for Metals and Radionuclides

Soil

Scope of Work

Surface soil samples (0–5 cm) were collected from the front and back yards of all residential properties in the Village of Deloro, as well as from six properties north of Deloro Dam Road and two properties west of the village (145 stations) by MOE. Soil samples were sent to the MOE analytical laboratories for analysis of selected metals (aluminum, barium, beryllium, calcium, cadmium, chromium, cobalt, copper, iron, lead, magnesium, manganese, molybdenum, nickel, strontium, vanadium, zinc, arsenic, silver, and uranium) and to the Ministry of Labour analytical laboratories for analysis of selected radionuclides (Cs-137, K-40, Ra-226, Ra-228, Th-228, and U-238). Depth samples (0–5, 5–10, and 10–15 cm) were also collected from eight properties selected to represent the north, middle, and south areas of the village.

Findings

Surficial soil samples from residential properties in the Village of Deloro were found to be contaminated with arsenic, cobalt, and lead. Of the 145 stations sampled, soil concentrations exceeded the cleanup guideline for arsenic at 123 stations, for cobalt at 59 stations, and for lead at 25 stations. Maximum concentrations were 605 µg/g compared to the MOE soil cleanup guideline of 25 µg/g for arsenic; 340 µg/g compared to the MOE soil cleanup guideline of 50 µg/g for cobalt; and 655 µg/g compared to the MOE soil cleanup guideline of 200 µg/g for lead. Barium, copper, nickel, silver, strontium, uranium, and zinc all exceeded their respective OTR98 (Ontario Typical Range) values, but none exceeded their respective soil cleanup guidelines. Contour maps of arsenic, lead, cobalt, nickel, and silver as provided by the MOE in its 1999 Phytotoxicity Report are presented in Appendix E.

Radionuclide concentrations in soil were within the range of typical concentrations in Ontario. Depth sampling indicated that there was no consistent pattern of either increase or decrease of contamination with depth.

Garden Vegetable Study

Scope of Work

Garden vegetables and garden soil samples were collected from nearly all residential properties in the Village of Deloro where it was deemed that there was a substantial garden from which vegetables could be eaten regularly. These gardens tended not to be located in the most contaminated areas of the village. Garden soil samples were collected to a depth of 15 cm in seven gardens and analyzed for the same parameters as listed above for the residential soils. Vegetables (beans, beets, carrots, and lettuce) were planted from seed in the gardens in Deloro and in a control garden at the MOE laboratory. Plants were chosen to represent root crops (carrots, beets) and leaf crops (lettuce). Beans were chosen based on their known sensitivity to arsenic. Vegetables were analyzed for barium, beryllium, boron, cadmium, chromium, cobalt, copper, lead, molybdenum, nickel, strontium, vanadium, zinc, arsenic, selenium, and uranium.

Findings

Soil samples from the gardens were found to be significantly contaminated with arsenic and in one garden with lead, and marginally contaminated with cobalt, barium, lead, nickel, silver, strontium, and zinc. Maximum concentrations were 100 µg/g compared to the MOE soil cleanup guideline of 25 µg/g for arsenic; 74 µg/g compared to the MOE soil cleanup guideline of 50 µg/g for cobalt; and 265 µg/g compared to the MOE soil cleanup guideline of 200 µg/g for lead. Barium, nickel, silver, strontium, and zinc all exceeded their respective OTR98 (Ontario Typical Range) values, but none exceeded their respective soil cleanup guidelines. There was relatively little uptake of any of these contaminants into bean pods, beet roots, or lettuce leaves. Lead concentrations were inexplicably high in carrot in two gardens. Levels of uptake of arsenic into plants were low and indicated that arsenic is not readily available in the garden soil.

Indoor Sampling

Scope of Work

Fifty-six sampling locations were identified for the indoor air and dust sampling in the Village of Deloro, and two locations were identified outside of the village (Figures 2-1 and 2-2). The sampling locations comprised 53 households in the study area, the Townhall/Library, the municipal well pumphouse and a youth centre in the Village of Deloro, one household outside of Deloro, and the Marmora Township office.

The indoor sampling involved the following:

- Sampling for selected metals (arsenic, nickel, silver, lead, cobalt) and uranium in indoor air and settled dust was conducted for all households willing to participate in the study, in public buildings in the Village of Deloro, and in two locations outside the study area.
- Sampling was completed during generally dry and dusty conditions. Since samples were collected during periods of high dust movement, they are considered representative of typical conditions in the Village of Deloro.
- Indoor air samples were collected from two locations in each building: one on the main level near the common entranceway and one in a common area such as a living room or dining room. For households with children, one sample was collected from the most common indoor play area.
- As it was expected that dusts inside the homes would be contaminated with metals (based on the soil results), swipe samples of interior surface dust were collected from each home to confirm the presence or absence of contaminants in readily accessible areas of exposure in a home. This method was chosen over vacuum pump sampling so as not to underestimate levels of contaminants.
- Sampling for total radioactivity in indoor settled dust was conducted in all households willing to participate in the study, in public buildings in the Village of Deloro, and in two locations outside the study area.
- Sampling for selected radionuclides (Po-210, Pb-210, Ra-226, and Th-230) in indoor settled dust was conducted for a subset of 15 households to allow the determination of the equilibrium ratios of these radionuclides within the uranium decay series (undertaken as part of Task VI).
- Comparison of the analytical results to applicable criteria (where available).
- Comparison of the results to typical Ontario concentrations (where available) and to results collected from outside the study area as part of this study.

Findings

In summary, the analyses of all samples collected were compared to available provincial and federal guidelines, to typical Ontario ranges (where available), and to samples collected from outside the study area (comparison locations). Comparison or reference samples were taken for air and dust at the Marmora Township office (Reference 1) and at the southwest edge of the Village of Deloro, approximately one kilometre west of the

village proper (Reference 2). Since the predominant wind direction is from the west and southwest, it is expected that these comparison locations would not be affected, or not as affected as the village proper, from blowing dust from the former mine/refinery site.

Indoor Air. All levels of airborne cobalt, lead, silver, arsenic, and uranium were below the method detection limits. Method detection limits varied depending on the volume of air sampled. Method detection limits for 9 of the 112 samples collected exceeded the outdoor criterion used for arsenic. There are no available criteria for indoor air.

Of the 112 samples collected within the study area (two per building), one detectable level of airborne nickel (0.403 $\mu g/m^3$) was measured. This value does not exceed the outdoor criterion used for nickel (2 $\mu g/m^3$). There are no available criteria for indoor air.

Indoor Dust Swipes. Nickel was detected in dust collected from most of the buildings sampled in the study area (52 out of 56 buildings). Arsenic was detected in 15 samples, lead was detected in 13 samples, cobalt was detected in six samples, and silver was detected in one sample. Uranium levels in all samples were below the method detection limit. There are no available criteria for indoor swipes and no typical Ontario values. Levels of all metals in indoor swipes in the study area were similar to those collected at the comparison location in Marmora with the exception of nickel, which was higher in the study area. Levels of metals in the study area samples were generally similar to, or greater than, levels at the comparison location one kilometre west of the village proper.

The measurable levels of radionuclide activity for the two comparison locations were generally greater than the levels within the study area.

Dustfall. Lead was detected in four of 56 dustfall samples collected from the buildings located in the study area. Nickel was detected in 15, and Pb-210 in six. Total radioactivity was detected in about one third of the samples. Levels were corrected for a 30-day interval and compared to levels found at the comparison locations, as there are no available criterion for dustfall other than for lead. None of the samples exceeded the lead criterion (0.1 $g/m^2/30$ days). Levels of metals in indoor dustfall in the study area were generally lower than at the two comparison locations. The measurable levels of radionuclide activity for the two comparison locations were generally equal to or less than the levels within the study area; however, the total radioactivity was generally equal to or greater than at the comparison locations.

Outdoor Air and Dust

Scope of Work

Ten outdoor air and dustfall sampling locations were selected. Eight of these locations were located throughout the village study area (Figures 2-1 and 2-2) and two of these locations were located outside the study area for comparison (Figure 1-1).

The outdoor sampling involved the following:

- Sampling for selected metals (arsenic, nickel, silver, lead, cobalt), selected radionuclides (Po-210, Pb-210, Ra-226, and Th-230), and uranium in outdoor air and settled dust at eight locations in the Village of Deloro and in two locations outside the study area.

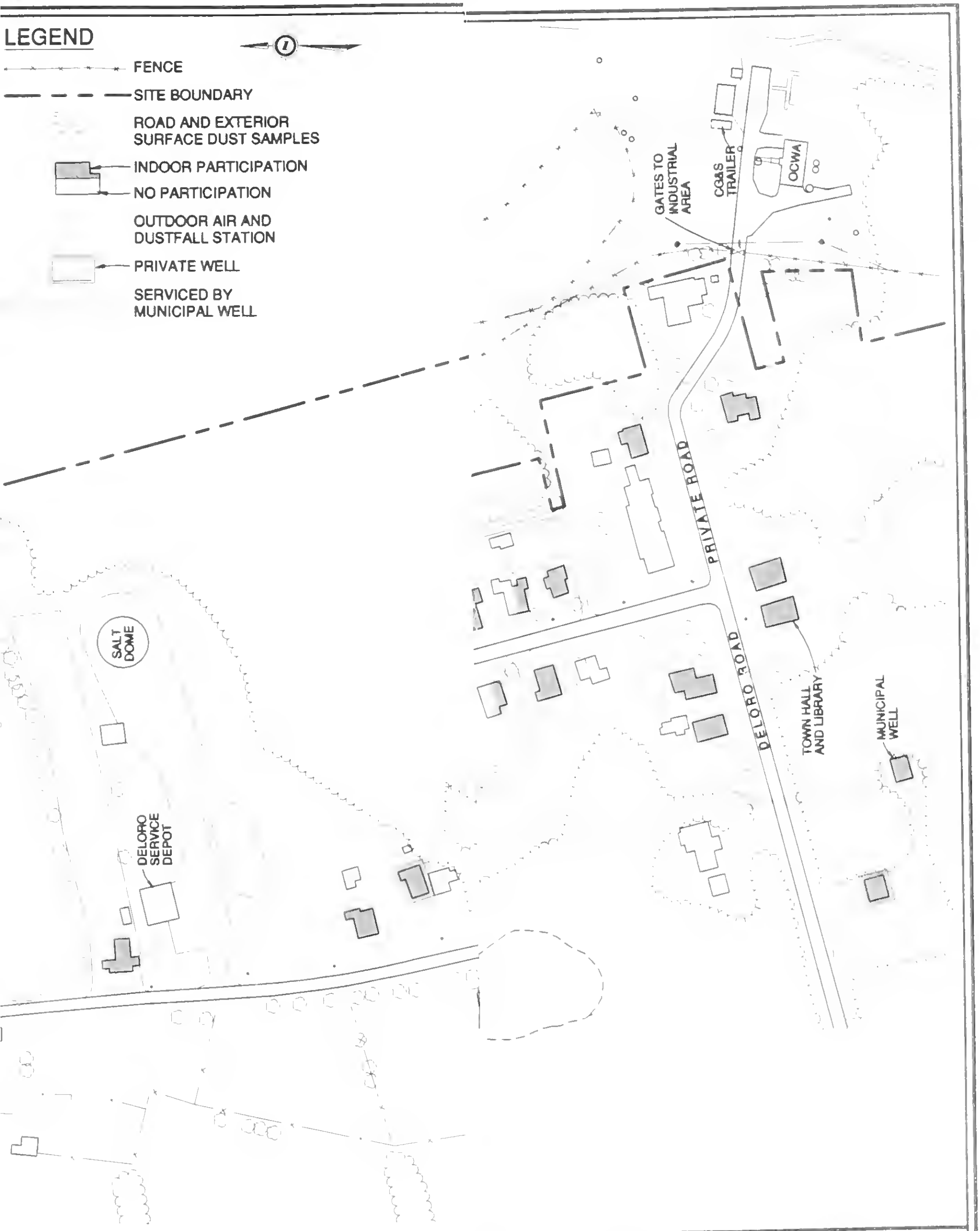

Figure 2-1
Village of Deloro
Health Risk Study
Sampling Locations

17/MAR/98

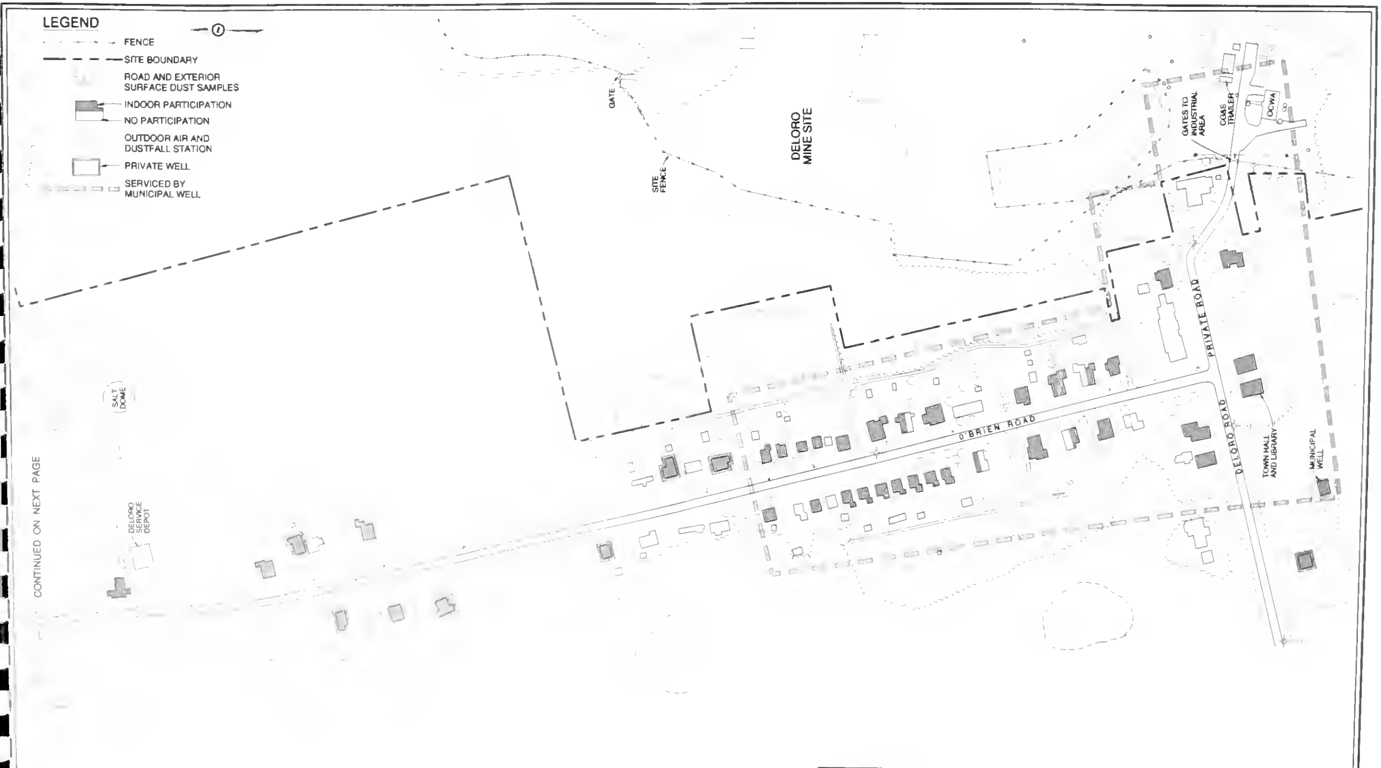

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Figure 2-1
Village of Deloro
Health Risk Study
Sampling Locations

17/MAR/98

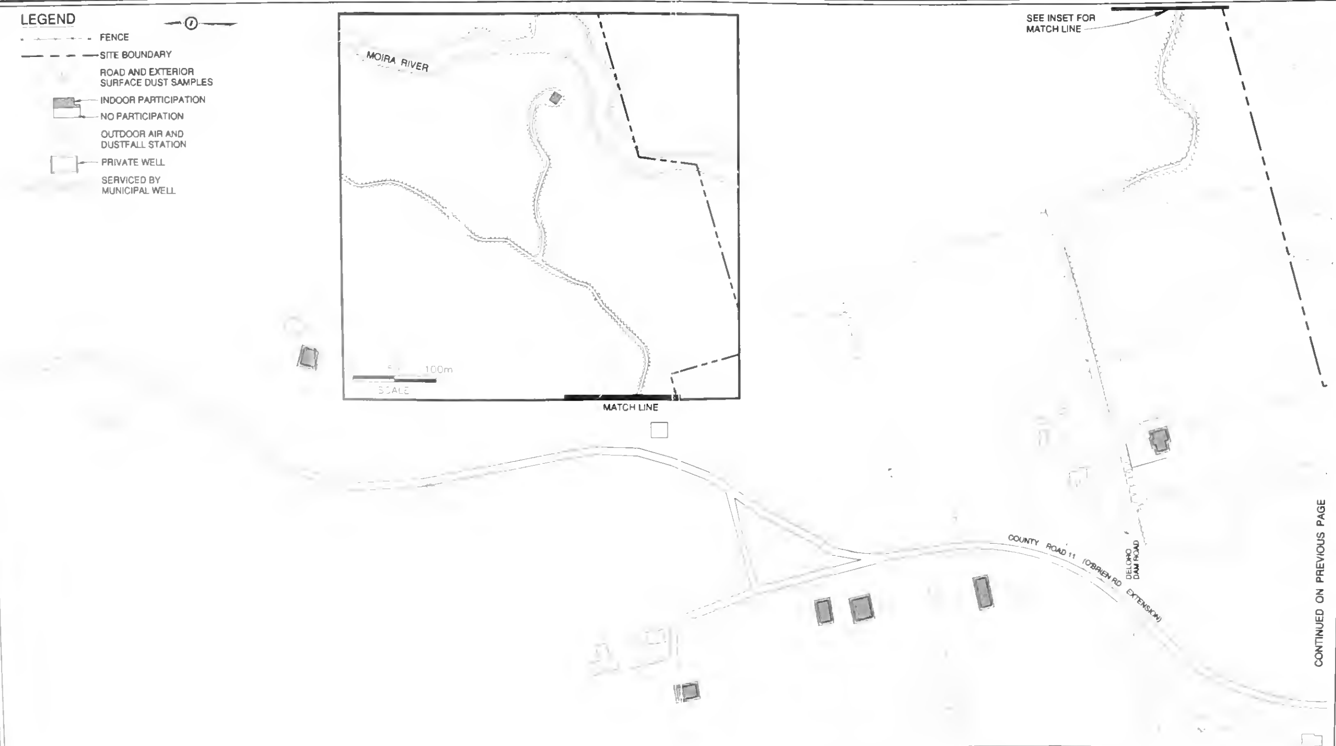

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Figure 2-2
Village of Deloro
Health Risk Study
Sampling Locations

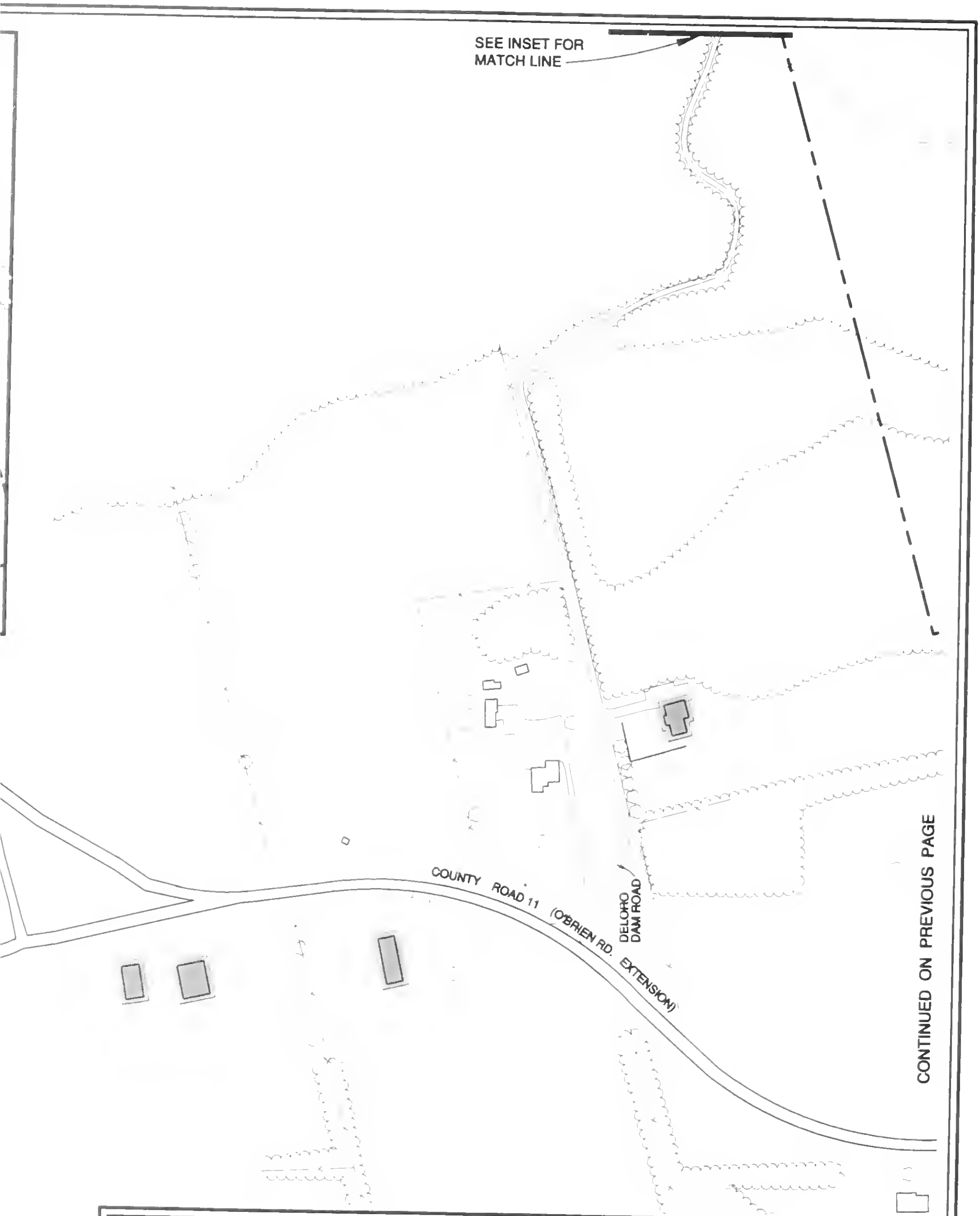

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Figure 2-2
Village of Deloro
Health Risk Study
Sampling Locations

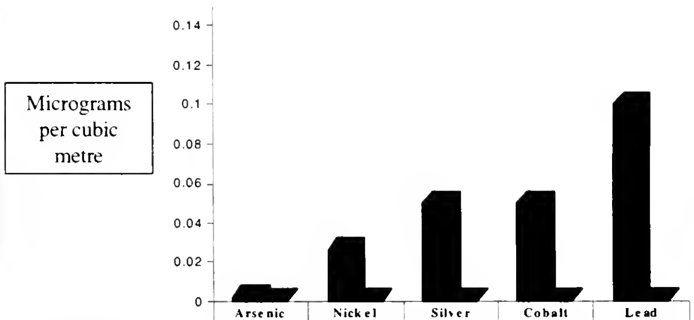
- Comparison of the analytical results to applicable criteria (where available).
- Comparison of the results to typical Ontario concentrations (where available) and to results collected from comparison locations.

Findings

In summary, the analyses of all samples collected were compared to available provincial and federal guidelines, to typical Ontario ranges (where available), and to samples collected from outside the study area (comparison locations). Comparison or reference samples were taken for air and dust at the Marmora Township office (Reference 1) and at the southwest edge of the Village of Deloro, approximately one kilometre west of the village proper (Reference 2). Since the predominant wind direction is from the west and southwest, it is expected that these comparison locations would not be affected, or not as affected as the village proper, from blowing dust from the former mine/refinery site.

Outdoor Air. There were detects of metals (concentrations greater than the laboratory reporting limit) in less than half of the 80 outdoor air samples, but all samples had detects of radionuclides. None of the detects of metals exceeded current outdoor ambient air quality guidelines (MOE Reg 337 for a 24-hour period). As shown in Figure 2-3, metal levels were all below the typical values for Ontario [0.001 to 0.002 µg/m^3 for arsenic (MOE, 1996), 0.001 to 0.026 for nickel (Dann, 1990, 1991), <0.05 for silver (WHO, 1984) and cobalt (Donaldson et al., 1986) and <0.1 for lead (EC, 1991)]. There are no criteria for radionuclides for comparison; however, the values are in the range of typical background levels.

FIGURE 2-3
COMPARISON OF OUTDOOR AIR QUALITY IN DELORO TO TYPICAL ONTARIO



	Arsenic	Nickel	Silver	Cobalt	Lead
■ Typical Ontario	<0.002	0.026	<0.05	<0.05	<0.1
■ Deloro Outdoor Maximum	0.00045	0.0006	<0.00022	<0.00022	0.00041

Metals concentrations in outdoor air were generally higher than at the comparison location in Marmora and generally the same as at the comparison location one kilometre west of the village. The radionuclide concentrations in the study area were generally

higher than at the comparison location in Marmora and generally lower than at the comparison location.

Road Dust. Most of the seven swipe samples for road dust collected in the study area had detects of metals (excluding silver) and radionuclides. There are no criteria for outdoor swipe samples and no typical Ontario values. Metal levels at the comparison location in Marmora were generally less than or equal to metal levels in the study area samples with the exception of arsenic, which exceeded the arsenic levels in six of seven samples. Metal levels at the comparison location one kilometre west of the village exceeded or equalled study area levels in almost all cases. Radionuclide levels in the study area were generally higher than those found at the comparison locations.

Exterior Surface Dust. Seven of the eight exterior surface dust samples had detects in both metals and radionuclides. There are no criteria for swipe samples of exterior surface dust and no typical Ontario values. Metal levels found in the study area generally exceeded or equalled metal levels found at the comparison location in Marmora.

Outdoor Dustfall. The outdoor dustfall samples contained debris that had accumulated in the sampling containers. As a result, possible interference resulted in high method detection limits for the outdoor dust samples. Of the ten sample locations, only two locations contained detectable levels of arsenic. Both of these sample locations were located adjacent to the former mine site. The values measured for lead did not exceed the lead dustfall criterion (0.1 $g/m^2/30$ days).

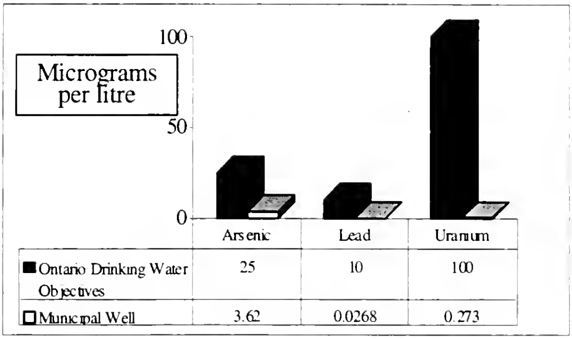
Drinking Water. The municipal well was tested for a subset of radionuclides by CG&S. Data from testing performed by the Ontario Clean Water Agency (OCWA) in May 1994, April 1998, July 1998, and February 1999 were also reviewed. Figures 2-1 and 2-2 show the extent of the municipal well distribution system as well as the participating homes that use a private well for drinking water. The location of the municipal well is also shown. First-draw and flushed water samples were collected from private wells at 15 residences. The first-draw samples were collected early in the morning, before residents used their wells. Consequently, the first-draw samples should be representative of an approximately eight-hour period of zero usage. Flushed water samples were obtained by running the water tap for a minimum of five minutes to flush the water system and ensure that fresh water samples were obtained.

Samples were obtained from an outside tap; hoses were removed where possible. The homes that had water treatment systems set their systems to bypass during the sampling period to permit collection of untreated samples. The municipal supply well and private wells from participating residences were sampled for selected metals (arsenic, nickel, silver, lead, cobalt), selected radionuclides (Po-210, Pb-210, Ra-226, Th-230, Th-232, Cs-137, I-131, Sr-90, and tritium), and uranium. Results were compared to the Ontario Drinking Water Objectives (MOE, 1994), to the Guidelines for Use at Contaminated Sites in Ontario - Table A (MOE, 1997), and to Health Canada criteria (where ODWO values were not available).

Findings

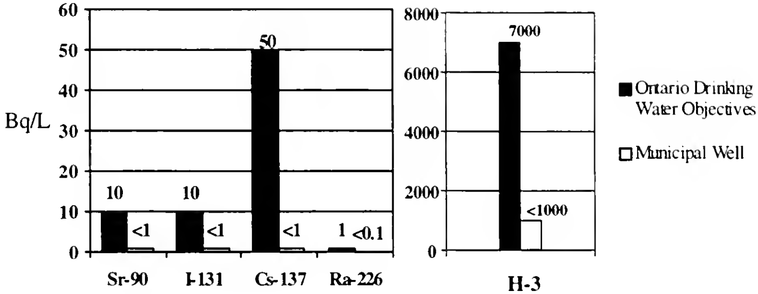
All of the municipal well samples met the drinking water guidelines. A comparison of selected compounds to the Ontario Drinking Water Objectives is provided in Figures 2-4 and 2-5.

FIGURE 2-4
ARSENIC, LEAD, AND URANIUM MEASURED IN THE MUNICIPAL WATER SYSTEM



	Arsenic	Lead	Uranium
■ Ontario Drinking Water Objectives	25	10	100
□ Municipal Well	3.62	0.0268	0.273

FIGURE 2-5
RADIONUCLIDES MEASURED IN THE MUNICIPAL WATER SYSTEM



Outdoor Air to Soil

There is no perceptible correlation between concentrations of contaminants in outdoor air to concentrations of contaminants in soil.

Road Dust to Soil

Arsenic and radium-226 were found throughout the village in soil and in all road dust samples. Cobalt and lead were detected in six of seven road dust samples, but were limited to the south area in soils. There was no apparent correlation between higher soil sample concentrations and higher road dust sample values.

Exterior Surface Dust to Soil

Because of the number of non-detectable values, meaningful correlations could not be determined.

Outdoor Dustfall to Soil

Because of the number of non-detectable values, meaningful correlations could not be determined.

Indoor Air to Soil

Because of the number of non-detectable values, meaningful correlations could not be determined.

Indoor Swipes for Dust to Soil

Arsenic and lead values in swipe samples did not correlate to values in soil. Cobalt concentrations in indoor dust samples correlated well to corresponding concentrations of cobalt in soil near the households. There was no relationship between the soil concentrations and concentrations in swipe samples for radionuclides.

Indoor Settled Dust to Soil

Because of the number of non-detectable values, meaningful correlations for metals could not be determined. There is no correlation between gross radioactivity in settled dust and radionuclides in soils.

Environmental Sampling and Analysis for Radioactivity

SENES Consultants Ltd., with the assistance of the Low-Level Radioactive Waste Management Office, conducted radiation monitoring within the Village of Deloro. The types of sampling and analysis were as follows:

- Indoor radon gas measurements in participating private residences within the Village of Deloro; outdoor radon gas measurements at 11 locations selected by the project management team; and outdoor gamma radiation measurements on participating private properties and public areas within the Village of Deloro.

Indoor Radon Gas

Scope of Work

Indoor radon gas concentrations were measured in 57 participating homes within the village using passive E-PERM Electret radon monitors. The E-PERMs were placed in pairs (i.e. replicate measurements) at designated locations in each home. The replicate measurements were averaged to determine the concentration at each location. One pair of monitors was placed within the main floor living area where residents spend much of their time, while the other pair of monitors was deployed either in the basement area (where the radon in air concentrations are expected to be highest), or, if there was no basement, in an upper-floor area. The monitors remained in place for approximately two weeks.

Findings

The average concentration for a Deloro Village home main floor is 56 Bq/m^3, while the average for a basement area is 101 Bq/m^3. The maximum concentration measured in the 57 homes on the main floor was 284 Bq/m^3, while the maximum in a basement area was

392 Bq/m^3. Based on a review of the radon gas data, the living areas of 10 residences and the Deloro pumphouse have or may be close to having radon and corresponding radon daughter concentrations in excess of the 1977 Federal Provincial Task Force criterion for radon of approximately 150 Bq/m^3, corresponding to a radon progeny level of 0.02 working levels. The 1977 criterion sets the primary cleanup or remedial action level for radon daughters at 0.02 working levels (WL). This criterion is more restrictive than the more recent 1988 radon guideline developed by Health Canada, which recommends that remedial actions be implemented if radon levels in indoor air, as an estimated annual average in a normal living area, are greater than 800 Bq/m^3.

It is important to note that while the radon levels in the 10 residences and the pumphouse approached or exceeded the 1977 Federal Provincial Task Force criterion, none of the measured values exceeded the Health Canada guideline for radon, considered to represent a level at which remedial measures should be taken.

All of the radon levels were within the range of variability of typical levels in Ontario.

Outdoor Radon Gas

Scope of Work

Replicate E-PERMs were deployed within protective shelters at the 11 ambient air monitoring stations (10 sites within the village and one in Marmora, where dustfall and suspended particulate samplers had been deployed) for a period of approximately four weeks.

Findings

Most stations show radon levels below an effective reporting limit of 10 Bq/m^3. The highest value is 28.9 Bq/m^3 at Station 11 (near the main entrance to the mine site).

There are no criteria for outdoor radon. The highest outdoor radon concentration was measured on the vacant lot near the main entrance to the former mine site. The data do not indicate a distinctive trend in concentrations versus distance from the former mine site.

Outdoor Gamma Radiation

Scope of Work

Gamma radiation measurements were taken across the surface of participating private properties using scintillometer radiation detectors (scintillometers are well suited for this type of monitoring because of their reliability and sensitivity to minor variations in background gamma radiation levels). These scintillometers were connected to individual recording and analyzing instruments (e.g. ratemeters, scalers, dataloggers, etc.) designed for specific types of applications required during the course of the Deloro Village investigations. The various radiation monitoring systems used during the 1998 program in Deloro were:

- Large Area Gamma Survey (LAGS) System,
- Roving GPS/Gamma Survey System, and
- Hand-Held Gamma Survey System.

Gamma surveys using the LAGS cart system were conducted on 63 private occupied residential properties within the study area. In addition to these private residential properties, LAGS surveys were also conducted on:

- The village's park area and baseball field located to the west of O'Brien Road,
- The property in the immediate vicinity of the Deloro Pumphouse,
- The yard area to the rear of the Community Hall/Library building, and
- The accessible portions of the vacant lot near the main gate to the former mine site.

Roving GPS gamma surveys were conducted:

- Along the rear laneway east of O'Brien Road,
- Along portions of the rear laneway to the west of O'Brien Road,
- Along the Deloro Dam Roadway,
- Along the series of recreational trails located to the east of the main village,
- Along the western perimeter fence line of the former mine site between the northern recreational trail area to the main gate into the site, and
- In several of the open fields adjacent to the homes in the northern part of the study area.

Findings

More than 175,000 gamma radiation measurements were recorded during the course of the October 1998 investigations. The results of the gamma survey are depicted in Figure 2-6. The average outdoor gamma radiation exposure rate for a Deloro Village residential property is 6.7 µR/hr and ranges between a minimum of less than the detection rate of 3.0 µR/hr and a maximum of 55.5 µR/hr. For commonly used outdoor areas other than residential properties (e.g. laneways, village park, recreational trails), the gamma radiation exposure rates range between less than the detection rate of 3.0 µR/hr and 54.8 µR/hr. For the vacant lot near the main entrance to the mine site, the average gamma radiation exposure rate was 47.9 µR/hr with individual measurements ranging between 11.7 and 467.7 µR/hr. The 1977 Federal Provincial Task Force also established a primary criterion for gamma radiation outside buildings of 100 uR/hr at a height of one metre above the ground. An exceedance of this criterion prompted remedial action to reduce levels to as low as reasonably achievable (ALARA) taking social and economic factors into consideration. A review of the data indicates that this criterion is exceeded on one property, specifically the vacant lot near the main entrance to the former mine site. One metre above ground height gamma radiation exposure rates on this property exceed the 1977 Task Force criterion along the eastern perimeter of the vacant lot. Elevated gamma radiation exposure rates are present predominantly in the southeastern corner of the study area, in the vicinity of the main gate to the former mine site. Much of the gamma radiation is attributed to gamma radiation shine from radioactive material located on the former mine site. The range of influence of this material is limited, and the gamma radiation exposure rates decrease rapidly with distance and reach background levels within a few hundred metres of the western site boundary.

FIGURE 2-6
RESULTS OF THE GAMMA SURVEY CONDUCTED IN DELORO

3. Task IV – Biological Monitoring, Risk Factor Questionnaires, and Analysis

A biological monitoring program was conducted to measure and assess the health significance of environmental exposure to arsenic. The program involved urinary arsenic tests, administration of a detailed risk factor and health status questionnaire, and determination of total and speciated arsenic levels in urine. Urinary arsenic tests are recognized in the medical community as the best method of measuring recent environmental exposure to arsenic. It is also the most sensitive test for looking at low-level exposures and the actual bodily dose to people. Tests of hair can indicate past exposures of up to 6–12 months but are not considered useful for detecting low-level exposure. Urinary arsenic testing is also the only method for which the health significance of the levels can be judged because some guidelines exist for total arsenic and there is information on speciated arsenic which can serve as a benchmark for health interpretation.

It has been acknowledged in the literature that much of the "total arsenic" could be a measure of exposure to organic sources (e.g. seafish meal) and these sources possess no danger to the health of the person. However, "speciated (inorganic) arsenic," is identified in the literature as potential cause for concern, at least with respect to some acute symptoms and some chronic diseases. It is this latter measure that was the main focus of the urinary arsenic analysis.

Scope of Work

Goss Gilroy Inc. conducted the biological component of this study. This component was comprised of the following:

- The collection of urine samples from 121 volunteers in the Village of Deloro (80 percent of the population) and 53 volunteers from Havelock to compare the level of arsenic in urine for residents of Deloro with a comparable (control) community that did not have any identifiable source of arsenic contamination;
- The collection, analysis, and profiling of data on the socio-demographics, health, and environmental characteristics and diet patterns of the residents of Deloro with a comparable community through the use of an environmental health risk questionnaire (completed for 140 volunteers from Deloro and 54 volunteers from Havelock);
- Conducting a quantitative analysis of risk factors, testing specific hypotheses of association between urinary arsenic and levels in environmental media.

The survey included all residents of Deloro and a sample of residents from Havelock, a community that was of comparable size and other characteristics and that did not have a history of exposure to arsenic in the environment. Since the entire population of

Deloro was included in the study, the results show a true picture of body burden of arsenic as measured by first-void morning urine samples.

The results describe the characteristics of the population in Deloro. Since it was a complete census of residents of Deloro and represented at least 80 percent of the households/residents in the study, this report presents a reliable picture of the levels of urinary arsenic and other risk factors in this population.

Approach

Urine samples were collected using standard medical protocols. All testing of urine samples was completed by Maxxam Analytics Inc., Occupational Health Sciences Lab (Etobicoke, Ontario) a certified laboratory. Each sample was tested for total arsenic (organic and inorganic forms), speciated arsenic (As(III), As(V), MMA, DMA), and creatinine. A method detection limit of 6 µg/L was used, which is well below the normal range levels and was appropriate for this study. Lower detection limits, although achieveable, were unnecessary. The protocols in accordance with Ministry of Health requirements were developed by Maxxam and reviewed by Goss Gilroy and the Technical Steering Committee scientific experts.

The field data collection activities for Deloro and Havelock were carried out over the time period September 24 to October 17, and November 5 to 16, 1998, respectively. Measurement of arsenic in urine was conducted in the fall of 1998, scheduled at a time when dust exposures were anticipated to be generally high and dry conditions exist to capture the high possible exposures. Arsenic in urine was selected as the best method to measure recent exposures because it is sensitive to low levels of exposure, is comparable to results in other similar studies, and because there are existing criteria against which the health importance of the finding can be interpreted.

Findings

Urinary Arsenic Results

Two of the Deloro respondents showed a level of total arsenic above 150 micrograms per litre of urine. These values are above the normal range used by physicians when screening for acute arsenic poisoning. These people were advised to consult with their family doctors. In addition, comprehensive information packages were provided to each individual's family physician.

Three other residents (two in Deloro, one in Havelock) had levels of speciated (inorganic) urinary arsenic 20 micrograms per litre of urine or greater, and they too were advised to visit their family physicians (refer to Figures 3-1 and 3-2). The normal range level for speciated urinary arsenic is a subject of much international research, and some experts have suggested a level of 25 µg/L. Although no resident in the Deloro/Havelock study exceeded 25 µg/L, it was nevertheless deemed prudent to invoke follow-up procedures.

FIGURE 3-1
SPECIATED URINARY ARSENIC RESULTS - DELORO

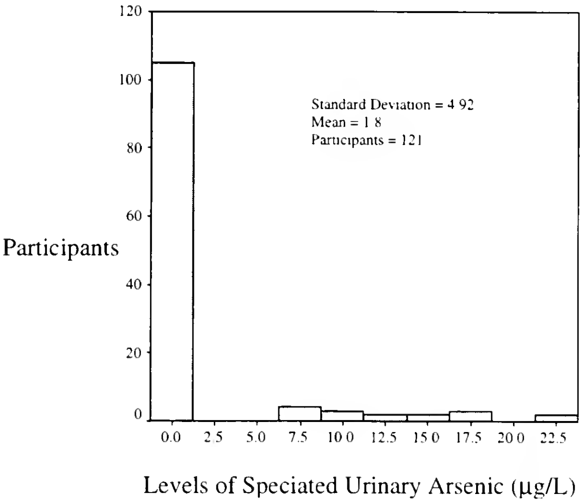
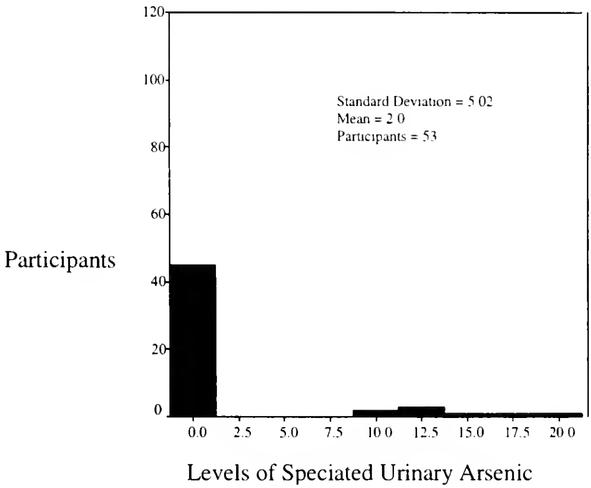


FIGURE 3-2
SPECIATED URINARY ARSENIC RESULTS - HAVELOCK



Creatinine markers may assist in the assessment of diluteness of the urine. The first internal results from MAXXAM for the biological samples contrasted the analysis of total/speciated urinary arsenic, using urine creatinine, with that of the more traditional presentation of results in µg/L (without urine creatinine). These results were examined by Goss Gilroy and the MOE and found to be quite similar in magnitude/interpretation. A literature review for urinary arsenic-based studies revealed previous studies using the traditional method of analysis. Therefore, creatinine markers were not used in the analysis of the report, because the use of creatine will not change the findings of the study and adds to comparability with other published studies.

In summary, with respect to all of these follow-ups, *it is emphasized that none of the five respondents who were advised to seek additional testing by their family physicians showed any adverse health effects or unusual exposure to other environmental or dietary factors, based on their responses to the health risk questionnaire.* It is noted that the sensitivity of the questionnaire and responses provided by individuals is important in order to make such a conclusion. In other words, there was nothing "unusual" about these five individuals as far as the data that were collected in this study. No relationships to reported adverse health effects or other potential risk factors could be identified.

Deloro–Havelock Comparisons for Urinary Arsenic

Overall, the respondents from Havelock had similar urinary arsenic results to those results from Deloro, except that all the Havelock respondents had total arsenic well below the 150 µg/L observed for two individuals from Deloro.

Statistical Comparisons and Results

Statistical comparison of the frequency distributions of urinary arsenic levels (total and speciated) and statistical tests of mean and median urinary arsenic levels showed no significant differences at the 5 percent significance level. *It is therefore reasonable to conclude that residents of Deloro do not appear to have, on average, higher levels of arsenic (total and speciated) than the comparison (control) community.*

Mean urinary arsenic levels (total as well as speciated) were compared for people reporting various health problems in the last year, and these were found to be not significantly different. *It is therefore reasonable to conclude that the levels of arsenic in this community are not indicative of any excess levels of morbidity as observed by their self-reports.* The health problems reported in Deloro were similar to those reported in Havelock, and appear similar to the general population.

Regression analysis showed that the urinary arsenic levels (total and speciated) could not be statistically associated with the characteristics of the population. Socio-demographic variables such as age, income, and education were similar for various levels of urinary arsenic. None of the regression coefficients were significant.

Characteristics of the places of residence, including the presence of vegetable gardens and use of well water as well as length of residence in Deloro, were also analyzed using a linear regression. None of the regression coefficients were statistically significant.

In addition, *the respondents with higher levels of arsenic were compared to those with lower levels, and none of the variables showed statistically significant association*. Since there was no overall difference in mean arsenic levels between Deloro (exposed community) and Havelock (unexposed community), this result is expected.

Normally, in statistical modelling, various subgroups of independent variables are investigated separately and the ones found to be significant are considered together in a final model. In this analysis, *since none of the separate regressions resulted in significant associations, a final model incorporating all the variables considered was not done*.

Data Limitations

Some of the variables were not considered in the regression analysis due to the non-descriptive nature of the data or because of a large number of missing observations (e.g. values below the detection limits). For example, the question on having a backyard was answered affirmatively by almost all respondents and therefore would be non-informative. The question on consumption of shellfish was answered by only a portion of the respondents and would have many missing values. Researchers could assign a value of "no consumption" to those who did not respond to the question and perform a regression analysis including this variable. This was not considered necessary, due to the relatively large number of separate analyses performed on the data set with no significant associations detected. Variables considered most reasonable to link with urinary arsenic were included in the separate analyses performed.

All of the regression analyses were done using Deloro data only. This was primarily because the complementary and follow-up analyses using environmental data would include only the Deloro community. For comparability, it was considered appropriate to include only these data. Adding the Havelock data to the analysis would improve the statistical power, although "village" will have to be included in the analysis as a separate independent variable (or, consider the two villages to be similar based on the univariate analysis comparing the mean arsenic levels). This type of (secondary) analysis was not performed as it would not substantially change any of the foregoing conclusions.

4. Epidemiological Study

The Hastings and Prince Edward Counties Health Unit conducted a health status review of cancer incidence and mortality data for Deloro and surrounding area, Hastings and Prince Edward Counties, and Eastern Ontario to review cancer incidence and mortality rates in Deloro and the population of the surrounding area (including downstream along the Moira River) from 1980 to 1995.

Scope of Work

Cancer incidence data from 1980 to 1995, cancer mortality data from 1981 to 1995, and census population figures were obtained from the Ontario Ministry of Health, Public Health Branch. Cancer data are collected by the Ontario Cancer Registry, and census data are collected by Statistics Canada. Reviews were conducted for cancer types including lip, oral cavity and pharynx; stomach; colorectal; pancreas; nasal cavity; lung; breast; cervix; prostate; bladder; kidney; leukemia; and all sites. The site-specific cancers were selected because they had been identified in the literature as being potentially associated with the contaminants present at the Deloro Mine Site or because they were relatively common cancers that could provide useful comparisons. Skin cancer was excluded because diagnosis and reporting of non-melanoma skin cancer is incomplete and unreliable.

Cancer cases for Deloro were grouped with those from other municipalities because there were too few cases in Deloro to release the information without violating guidelines for confidentiality or to calculate reliable statistics. Even so, some data will be suppressed in order to fulfill our requirement to not release data with a cell size less than five. The municipalities identified as "the surrounding area" were chosen based on their proximity to the Deloro Mine Site and their likelihood of having been exposed to either airborne or waterborne (via the Moira River) contamination from the mine site: Deloro Village, Huntingdon Township, Hungerford Township, Tweed, Madoc Township, Madoc Village, Marmora, and Lake Township. Potential contaminants were identified as arsenic, silver, zinc, nickel, and uranium. The time period of study was selected because it provided a relatively long time frame to study trends; the quality of cancer incidence and mortality data is highest for these years and data were accessible.

To enhance stability of estimates for small populations, and to increase accuracy of estimates for all areas, rates for all geographic regions were calculated for four time periods, each bracketing a census year: 1981, 1986, 1991, and 1996.

The process of indirect standardization was used to assess if any cancer rates in Deloro and surrounding area differed significantly from the provincial rates, taking into account the age structure of the population. Direct standardization was then used to make comparisons with other areas in Hastings and Prince Edward Counties and Eastern Ontario for cancers that had a statistically significant indirectly standardized incidence or mortality rate.

Findings

The study found significantly high and low standardized incidence and mortality rates for at least some cancers in every area within Hastings and Prince Edward Counties Health Unit. The following comments focus on significant findings for Deloro and surrounding areas.

With respect to mortality, summarized standardized mortality ratios were high for lung cancer [SMR 127.6, 95 percent CL 103.5, 154.3] and leukemia [147.6, 95 percent CL 100.2, 204.2] in males compared to Ontario, but not when compared to other areas in Hastings County. There was no evidence of a statistically significant trend over time, although leukemia mortality rates appeared to decrease from the early 1980s to the mid-1990s. Females had significantly low summarized standardized mortality ratios for leukemia [SMR 52.9, 95 percent CL 24.0, 93.2] and stomach cancer [SMR 33.3, 95 percent CL 3.1, 95.5] when compared to the province. The fact that the total number of observed leukemia deaths was almost exactly what would be expected suggests that the cases were distributed unevenly between the sexes by chance.

For Deloro and surrounding area, standardized incidence ratios were high for lung cancer [SIR 137.5, 95 percent CL 115.0, 162.0] in males compared to Ontario, but not when compared to other geographic areas in Hastings County. There was no evidence of a trend over time. Females had significantly low summarized standardized incidence ratios for stomach cancer [SIR 33.3, 95 percent CL 6.3, 81.7] and colorectal cancer [SIR 69.5, 95 percent CL 49.9, 92.4].

For the cancers studied, no incidence or mortality rate was high enough to suggest that further, more detailed, analysis was warranted for either males or females.

Limitations

Because a large number of comparisons were made at the 95 percent level of statistical significance, there is a high likelihood that some of the significant results occurred by chance—significant results were likely to occur in one out of 20 comparisons by chance alone.

The nature of the study design is such that the results provide only a description of cancer incidence and mortality in the areas of interest. No conclusions can be drawn and no associations can be inferred about any potential cause and effect relationships between exposures and outcomes.

5. Risk Assessments

Task V – Exposure Assessment and Health Risk Characterization for Metals

CANTOX Environmental Inc. (CANTOX) was retained to conduct an exposure assessment and health risk characterization for the residents of the Village of Deloro based on concentrations of arsenic, cobalt, lead, nickel, and silver potentially present in the air, water, soil, and food within the village. The study involved comparing the results to other arsenic health risk studies for individuals living near mining or smelting operations in North America; background exposure risks to typical Ontario residents; acceptable risk levels in Ontario; and biological monitoring results (urinary arsenic tests) completed by Goss Gilroy (refer to Task IV). This section of the report summarizes the information provided by CANTOX in its final report entitled Deloro Village Exposure Assessment and Health Risk Characterization for Arsenic and Other Metals. An additional five metals (beryllium, boron, cadmium, copper, and mercury) were found to be present on the former mine site at concentrations in excess of the applied guideline. These contaminants are supplementary to the five detected in the village (arsenic, cobalt, lead, nickel, and silver) that were retained for the village assessment. A supplementary trespasser scenario for exposure to these additional metals was completed by CG&S in addition to the trespasser scenario completed by CANTOX for arsenic, cobalt, lead, nickel, and silver. The results are presented later in this section.

Objectives

The objectives of this assessment were as follows:

(i) to review the exposures and/or risks posed to the public in the vicinity of other mining or smelting operations in North America;

(ii) to review the sources and levels of exposure of chemicals of concern to typical Ontarians, including home-grown and market basket foods, soils, drinking water, and air;

(iii) to determine if the concentrations of arsenic and the other metals of concern in various media in Deloro would pose a risk of adverse health effects for adults and children dwelling in the village, and to compare results to exposures in other mining/smelter areas as well as exposures of typical Ontario residents;

(iv) to compare the results of exposure assessment to those of biological monitoring efforts (specifically urinary arsenic determinations); and

(v) to review various options of exposure and risk mitigation and make estimates of possible risk reductions.

Review of Exposure to Arsenic

Arsenic is a naturally occurring element that is found in terrestrial and aquatic environments; it is capable of extensive cycling through both biotic and abiotic components of these systems. Therefore, while exposures to arsenic may be exacerbated by human activity such as mining (i.e. point sources), even populations without direct contact with such point sources will be exposed to arsenic at some level. Environment Canada has estimated that the total average daily intake of inorganic arsenic by Canadians without direct contact to point sources ranges from 0.1 to 2.6 µg/kg body weight/day, with the greatest exposure occurring in infants and young children. The MOE examined the relative contribution of various pathways of exposure to total daily intake of inorganic arsenic via ingestion for Ontario residents, and identified as major contributors both food (84%) and drinking water (15%). Soil/dust ingestion pathways contributed less than 1 percent to the total. Environment Canada estimated daily intakes of inorganic arsenic by Canadians living near point sources of arsenic contamination, from all exposure pathways, to range from <0.1 to 35 µg/kg body weight/day, with the greatest exposure occurring in infants and young children.

Analysis of concentrations of arsenic compounds in the urine is considered a reliable, non-intrusive technique for evaluating recent arsenic exposure, and thus serves as an indicator of the health status of populations exposed to arsenic. Total urinary arsenic concentrations reflect intakes of all forms of arsenic, including inorganic arsenic (considered to be responsible for toxicological effects associated with arsenic) as well as organic arsenicals (which are considered to be without significant toxicological effects). Therefore, speciated arsenic measurements, reflecting concentrations of only inorganic forms of arsenic and their metabolites (arsenic III, arsenic V, monomethylarsonic acid and dimethylarsonic acid) are generally considered the appropriate measure for use in health assessments. Populations not exposed to a point source of arsenic have average urinary speciated arsenic concentration of about 8 µg/L, in comparison to 52 µg/L reported for populations in the vicinity of mining or smelting operations, and 233 µg/L in populations exposed to arsenic occupationally or via high endemic concentrations in drinking water.

General Methodology for Metal Health Risk Assessment

The general methodology used for the health risk assessment consists of five phases: Phase I – Problem Formulation; Phase II – Exposure Assessment; Phase III – Hazard Assessment; Phase IV – Risk Characterization; and Phase V – Risk Management.

Phase I: Problem Formulation

In the problem formulation phase, the site and chemicals are characterized and the receptors and exposure pathways are identified.

Phase II: Exposure Assessment

The exposure assessment phase models the transport of a chemical from a source to a receptor through the environment to determine a rate of exposure. The assessment takes into account chemical-specific parameters, such as solubility and volatility; characteristics of the site, such as physical geography, geology and hydrogeology; and the physiology and behaviour of the receptors.

Phase III: Hazard Assessment

The hazard assessment phase provides a description of the toxic effect in humans relative to a specific dose and duration of exposure. Toxicological criteria available in the literature serve as the basis for the evaluation of the potential risks associated with exposure to a particular chemical. Different toxicological criteria are recommended for different routes of exposure. The bioavailability of a chemical is an important parameter to consider when determining an appropriate toxicological criterion.

The threshold approach applies to the non-carcinogenic effects of a chemical. No adverse effect will occur until some threshold limit (referred to as reference dose [RfD]) is exceeded. For non-threshold chemicals (carcinogenic chemicals), any exposure has the potential to cause damage or increase the likelihood of causing damage. Cancer slope factors (CSFs) and risk specific doses (RSDs) calculated based on an "acceptable" level of risk are used to evaluate these types of chemicals.

Phase IV: Risk Characterization

During the risk characterization phase, the exposure assessments and the hazard assessment results are combined to characterize the risks. For the threshold effects, the predicted exposure is divided by the toxicological criterion (RfD) for a particular route of exposure (inhalation, ingestion, or dermal). This ratio is commonly referred to as the Hazard Quotient (HQ) or the Exposure Ratio (ER), as used by CANTOX. If this value is less than one, an adverse effect is not anticipated. For non-threshold effects the predicted exposure, averaged over the lifetime of the individual, is multiplied by the cancer slope factor to determine an incremental lifetime cancer risk (ILCR) or cancer risk level (CRL), as termed by CANTOX. Based on the MOE's recommendations, an acceptable risk level of cancer induced in one person per million is frequently used. However, in some cases, the uncertainties and conservatisms associated with exposure and hazard assessment would mean that comparison to risks predicted relative to background levels may be more valid.

Each chemical is first assessed deterministically, at which point estimated ER and CRL values are determined. Those chemicals that reveal potentially unacceptable risk levels are then evaluated stochastically (probabilistically). Probability distribution functions are either generated or obtained from literature to be used for the input variables. The result is a distribution of risks and corresponding probabilities. The uncertainties of the assessment data process and results are discussed as part of the overall risk characterization.

Phase V: Risk Management

The last phase of the assessment is to recommend risk management options, if necessary: if the results of the risk characterization indicate that there are unacceptable risks posed to the receptors of concern, then recommendations on mitigation or reduction of those risks are made. In this case, information was collected regarding risk mitigation efforts and outcomes in other jurisdictions involving arsenic contamination to assess what might be appropriate to apply to Deloro with respect to risk management.

Problem Formulation

The village is located on the perimeter of the mine site and consists of 65 residences, many with sizable yards and home gardens. The area surrounding the village is rural, with both wooded areas and agricultural land. The population of Deloro consists of 140 citizens, 40 of which are children. The nearby Moira River, which runs through the mine site, is not used for swimming or fishing. However, villagers have been known to take periodic walks on the mine site.

Based on a screening-level soil assessment conducted by the MOE (1998), further characterization of arsenic, and to a lesser extent lead, nickel, cobalt, and silver, present in the village was required regarding the presence of these chemicals in other media and the potential risks they may pose to the residents of Deloro Village. Chemical data were collected for indoor/outdoor air suspended and settled dust, well water, and home-grown fruits/vegetables (refer to Section 2 - Task II).

Since physical characteristics, sensitivity to chemical exposure, and behaviour characteristics are age-dependent, villagers (receptors) from five age classes were selected: infant (0 to 6 months); preschool child (7 months to 4 years); child (5 years to 11 years); adolescent (12 to 19 years); and adult (20 years and over). In addition, a composite receptor was assessed for carcinogenic risk, representing cumulative exposure over an entire lifetime (which consists of each of the above age classes).

The exposure pathways evaluated include ingestion and dermal contact with soils and dusts indoors and outdoors; inhalation of dusts (particulate) indoors and outdoors; ingestion (drinking) of municipal or well water; and ingestion of homegrown and grocery-bought food.

For the purpose of the exposure assessment, the Village of Deloro was theoretically divided into four areas or zones (shown on Figures 1-2 and 1-3). Zone 1 is the most northerly, and Zone 4 is located adjacent to the mine site. Zone 1 refers to the media and site characterization data for residences north of 75 O'Brien Road; Zone 2 refers to residences between 43 and 75 O'Brien Road; Zone 3 consists of the remaining study area and residences with the exception of those located on Private Road or Zone 4, which is closest to the mine site.

Exposure scenarios describe the situations in which receptors may be exposed to chemicals of concern. An exposure scenario describes access to specific media, physical activity, time spent in contact with contaminated media, and so on. For this assessment, two exposure receptors were considered for each of the five age groups. Scenario No. 1 was a resident of Deloro. Scenario No. 2 considered a typical Ontario resident (Background).

The exposure Scenario No. 1 considered both children and teenagers, and adults (workers/ students) to be away from the village due to either work or school, and those individuals who do not leave the village on a regularly scheduled basis (i.e. stay-at-home residents). It was assumed that contaminant exposure when residents are away from Deloro would be at typical Ontario background levels. Infants, preschool children, and stay-at-home adults (i.e. a stay-at-home parent or a retired person), were assumed to occasionally leave town for various reasons, such as grocery shopping, visiting, and so on. Several variations of this scenario were examined with regard to the consumption

of home-garden produce, and also trespassing on the mine site. Time spent indoors and outdoors was adjusted for summer and winter months.

Exposure Scenario No. 2 used typical Ontario background concentrations in various media under conditions similar to Scenario No. 1.

Exposure Assessment

Exposure via all relevant pathways (oral, inhalation, or dermal contact with air, water, soil, dust, and food) was considered (see Figure 5-1). The major exposure pathways considered include outdoor/ indoor dust inhalation; outdoor soil ingestion; indoor dust ingestion; outdoor/indoor dermal contact; drinking water ingestion; home garden/store bought food ingestion. Dermal exposure in water through bathing was considered insignificant.

Hazard Assessment

The toxicity of each chemical is discussed in detail in the CANTOX study. A summary of the information is provided in Appendix E. Table 5.1 summarizes toxicological criteria selected for this study, the basis for the toxicological criteria, and the regulatory agency that adopted the limit. Bioavailability is an important consideration in the assessment of both exposure and toxicity. Bioavailability values selected for this assessment are summarized in Table 5.2.

Risk Characterization

For carcinogenic chemicals, risks are expressed as Cancer Risk Levels (CRLs) or levels of incremental cancer risk. Negligible cancer risk levels are generally considered to be 1×10^{-4} to 1×10^{-6}, but evaluation of predicted cancer risks for a population must also consider predicted risks for a background or "typical" population, since "typical" populations are considered to be without undue cancer risks. Predicted CRLs for these typical receptors provide a suitable level of risk. In cases where the estimated exposures or risks are not significantly different than the "typical" population risk, or that are in the range of risks considered negligible, it can be concluded that there would be no risk of adverse health effects. When estimated exposures or risks exceed these levels, consideration must be given to the possibility of adverse health effects; such exceedances are not necessarily indicative of potential risks, but may reflect overestimation of risk due to the use of overly conservative estimates (e.g. overestimating exposures through use of maximum soil ingestion rates, etc.). When evaluating risks, deterministic analyses were used initially, to characterize the plausible maximum ("worst-case") and typical mean exposures experienced by Deloro residents. In cases where the potential for measurable risks was indicated by comparison to the criteria and to risks of typical Ontario residents, it was concluded that a more rigorous and realistic evaluation of risks should be conducted through probabilistic analysis. The various uncertainties associated with each phase of the risk assessment were examined to ensure that the risk characterization would be both conservative and realistic. In all cases, the discussion and analysis of results focussed on the most sensitive receptor (composite, representing cumulative exposure throughout a lifetime for carcinogens, and infant or preschool child for non-carcinogens).

Figure 5-

Exposure Pathways for Human Health Risk Assessment

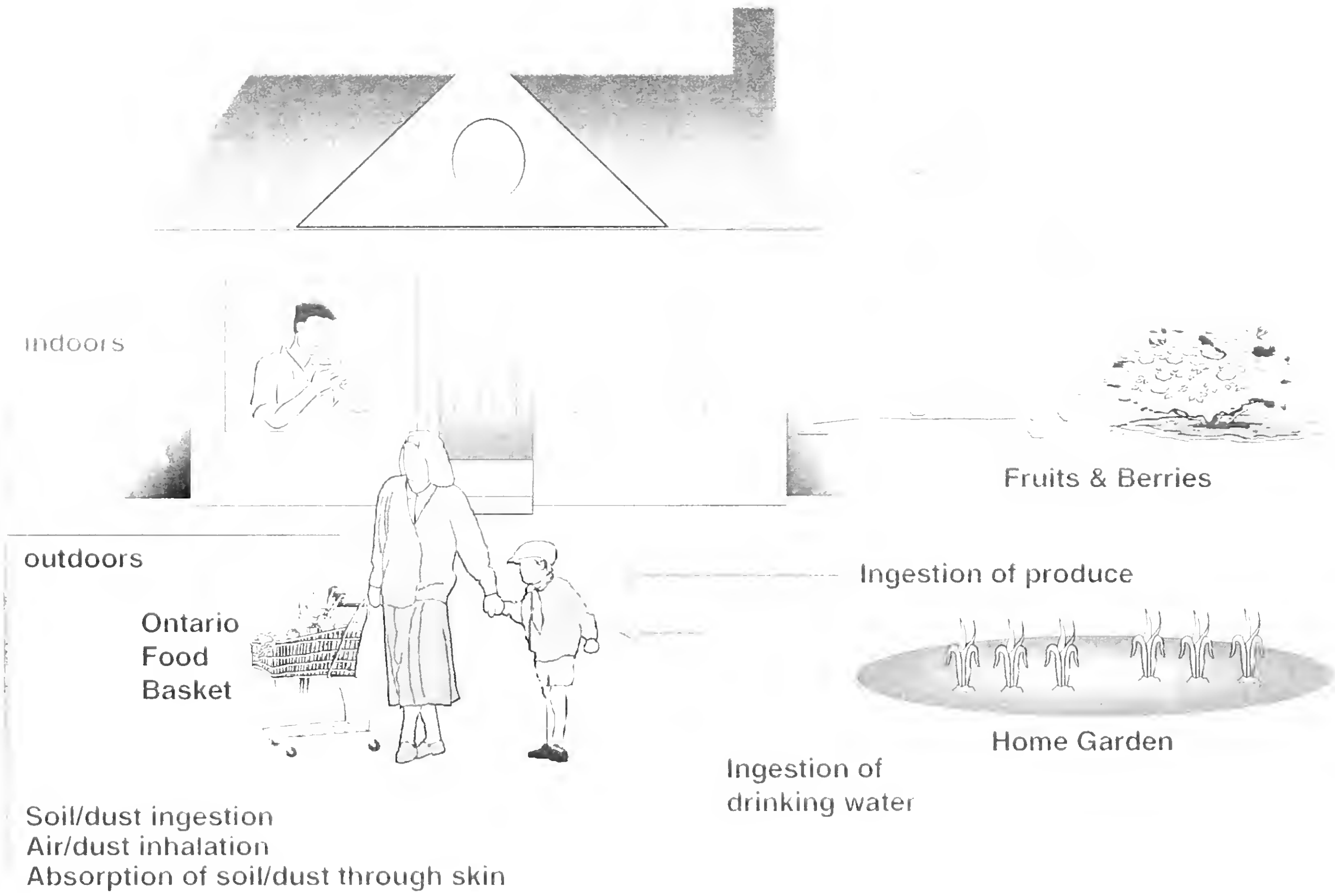


TABLE 5.1
SUMMARY OF TOXICOLOGICAL CRITERIA FOR HUMAN HEALTH RISK ASSESSMENT

Chemical	Route	Toxicological Criterion		Endpoint	Study	Regulatory Agency
		Type	Value			
Arsenic (non-carcinogenic)	Oral	RfD	0.3 μg/kg bw/d	hyperpigmentation, keratosis, possible vascular complications (human)	Tseng et al., 1968; Tseng, 1977	USEPA, 1998
Arsenic (carcinogenic)	Oral	q_1^*	0.0015 $(\mu g/kg\ bw/d)^{-1}$	skin cancer, basal, and squamous cell carcinoma (human)	Tseng et al., 1968; Tseng, 1977	USEPA, 1998
	Inhalation	q_1^*	0.013 $(\mu g/kg\ bw/d)^{-1}$	lung cancer (human)	Enterline and Marsh, 1982; Higgins, 1982; Brown and Chu, 1983a, b, c; Lee-Feldstein, 1983	USEPA, 1998
Cobalt	Oral	RfD	60 μg/kg bw/d	polycythemia (human)	not specified	USEPA, 1997
	Inhalation	RfD	0.01 μg/kg bw/d	metaplasia of larynx (rat/mouse)	Bucher et al., 1990; NTP, 1991	ATSDR, 1997
Lead	Oral	RfD	1.85 μg/kg bw/d	subclinical neurobehavioural and developmental effects (child)	MOE, 1994a	MOE, 1996
	Inhalation	RfD	1.85 μg/kg bw/d	subclinical neurobehavioural and developmental effects (child)	MOE, 1994a	MOE, 1996
Nickel	Oral	RfD	1.3 μg/kg bw/d	increased mortality of litter (rat)	Smith et al., 1993a	HC, 1996
	Inhalation	RfD	0.0012 μg/kg bw/d	lung and nasal lesions (rat/mouse)	Dunnick et al., 1989	HC, 1996
Silver	Oral	RfD	5 μg/kg bw/d	argyria (human)	Gaul and Staud, 1935	USEPA, 1998
	Inhalation	RfD	0.8 μg/kg bw/d	argyria of skin, eyes, and mucous membranes (human)	ACGIH, 1991	ACGIH, 1998

TABLE 5.2
SUMMARY OF BIOAVAILABILITY VALUES FOR HUMAN HEALTH RISK ASSESSMENT

Chemical	Bioavailability (%)					
	Oral	Reference	Inhalation	Reference	Dermal	Reference
Arsenic	95% 90% 14% 19%	in drinking water: Pomroy *et al.*, 1980 in food: MOE, 1994b in soil: Freeman *et al.*, 1995 in dust: Freeman *et al.*, 1995	30-34	Holland *et al.*, 1959	0.8-1.9	Wester *et al.*, 1993
Cobalt	18-97	Harp and Scoular, 1952; Sorbie *et al.*, 1971, Valberg *et al.*, 1969	24-71	APD[a]	0.06	Assumed[b]
Lead (adult)	10-15	Keho, 1961; Thompson, 1971; Karhausen, 1973; Blake, 1976; Chamberlain *et al.*, 1978	19-22	APD[a]	0.06	Moore *et al.*, 1980
Lead (child)	42-53	Karhausen, 1973; Alexander, 1974, Ziegler *et al.*, 1978; Mushak, 1991	38.2-44.8	APD[a]	0.06	Moore *et al.*, 1980
Nickel	1-10	USEPA, 1986; ATSDR, 1992; Nielsen *et al.*, 1993	13.6-19	APD[a]	0.06	Assumed[b]
Silver	4	Furchner *et al.*, 1968; USEPA, 1998	15.4	APD[a]	1	Wahlberg, 1965

[a]Airborne Particle Dynamics.
[b]Assumed to be the same dermal bioavailability as lead due to lack of data.

Arsenic (Carcinogenic). The composite receptor, representing cumulative exposure over a lifetime, had the highest cancer risk levels (CRL) (Table 5.3). Estimated maximum cancer risks are approximately 0.2 times higher than those for typical Ontario resident (99^{th} percentiles are 1.17 per 1,000 for Deloro versus 0.963 per 1,000 for Ontario). The predicted total cancer risk levels for the residents of Deloro, with and without consumption of home garden produce, were slightly higher than those predicted for typical Ontario residents (Tables 5.4 and 5.5). Deloro-related exposures contributed less than 0.1 per 1,000 to this risk. In the evaluation of specific cancer types (Table 5.6), it is apparent that the CRLs for lung cancer are significantly lower than those for skin cancer, indicating that the majority of the total cancer risk is due to risk of skin cancer (>99.95%). In addition, the predicted CRLs for lung cancer for Deloro residents were lower than those for Ontario residents, further supporting the conclusion that risks associated with exposure to Deloro-specific media are primarily, if not entirely, due to the risk of skin cancer.

The contribution of various pathways to intake of carcinogenic arsenic are provided in Figures 5-2 and 5-3 for the Preschool Child and Adult Deloro resident, respectively, as compared to the typical Ontario resident based on the probabilistic mean. The majority of the exposure for both the Deloro resident and the typical Ontario resident is from the general food basket (approximately 95% for typical Ontario and 80% for Deloro child or adult).

A detailed examination of the contributors to overall predicted skin cancer risks from arsenic for Deloro residents (consuming home garden produce) indicated that the general food basket common to all Ontarians were responsible up to 80 percent of overall exposures (Figure 5-4). The Deloro-related exposures making the greatest contribution to risks of Deloro residents was consumption of municipal drinking water. The concentrations in drinking water in Deloro were well below Ontario drinking water objectives for safety. Exposures through consumption of home garden produce, as well as dermal contact and ingestion of soil and dust ingestion were minimal (1.5% for garden produce, and 4% for all direct soil/dust pathways).

Negligible or *de minimis* cancer risk level is generally considered to be 1 in ten thousand ($1x10^{-4}$) to 1 in one million ($1x10^{-6}$), and risk estimates for a population that are greater than this level would be considered to be elevated. However, when estimates of cancer risk for typical Ontario residents exceed this negligible level of risk, it would be expected that the estimated risks for any population within Ontario, such as the residents of Deloro, would also exceed the level considered negligible. This is evident in the current assessment, as the CRLs for typical Ontario residents ranged from $2.9x10^{-4}$ to $9.63x10^{-4}$, while CRLs for Deloro residents ranged from $3.38x10^{-4}$ to $1.17x10^{-3}$; higher than typical Ontario by a factor of less than 0.2-fold. The elevation of risk for typical Ontario residents would indicate an overestimation of risk due to a high degree of conservatism in the risk assessment; the elevation of risks to Deloro residents, in large part, would be due to the same conservatism. Of considerable importance to the assessment of arsenic is the conservatism inherent in the dose-response relationship used in development of the cancer potency factor for arsenic by the USEPA. This conservatism would result in the overestimation of the potency of arsenic in inducing skin cancer, and consequently may lead to overestimation of predicted skin cancer risks, especially at lower rates of exposure more typical of most North American populations. To summarize briefly, the USEPA cancer potency is based

TABLE 5.3
PROBABILISTIC CANCER RISK LEVEL FOR ARSENIC EXPOSURE - COMPOSITE (LIFETIME) RECEPTOR

Exposure Pathway	Typical Ontario Resident									
	5th percentile		median		mean		95th percentile		99th percentile	
	CRL	%	CRL	%	CRL	%	CRL	%	CRL	%
Air	2.96e-6	1.02%	9.95e-6	1.87%	1.03e-5	1.87%	1.89e-5	2.22%	2.31e-5	2.40%
Soil and Indoor Dust	2.29e-6	0.79%	3.56e-6	0.67%	3.66e-6	0.67%	5.30e-6	0.62%	6.21e-6	0.65%
Drinking Water	1.44e-6	0.50%	1.56e-5	2.93%	1.76e-5	3.20%	4.07e-5	4.78%	5.50e-5	5.71%
Home Garden	1.41e-6	0.49%	2.57e-6	0.48%	2.82e-6	0.51%	5.07e-6	0.60%	7.23e-6	0.75%
General Food Basket	2.82e-4	97.21%	5.01e-4	94.05%	5.15e-4	93.74%	7.81e-4	91.78%	8.71e-4	90.49%
All Pathways Combined	2.90e-04	100.00%	5.33e-04	100.00%	5.49e-04	100.00%	8.51e-04	100.00%	9.63e-04	100.00%
	Deloro Resident									
	5th percentile		median		mean		95th percentile		99th percentile	
	CRL	%	CRL	%	CRL	%	CRL	%	CRL	%
Air	1.04e-6	0.31%	2.77e-6	0.45%	2.93e-6	0.46%	5.25e-6	0.52%	6.60e-6	0.56%
Soil and Indoor Dust	8.26e-6	2.44%	2.36e-5	3.85%	2.60e-5	4.08%	5.21e-5	5.18%	6.21e-6	5.81%
Drinking Water	4.48e-5	13.25%	7.87e-5	12.83%	8.50e-5	13.32%	1.47e-4	14.61%	1.67e-4	14.24%
Home Garden	2.10e-6	0.62%	7.41e-6	1.21%	8.99e-6	1.41%	2.09e-5	2.08%	5.97e-5	5.09%
General Food Basket	2.82e-4	83.38%	5.01e-4	81.67%	5.15e-4	80.73%	7.81e-4	77.61%	8.71e-4	74.29%
All Pathways Combined	3.38e-04	100.00%	6.13e-04	100.00%	6.38e-04	100.00%	1.01e-03	100.00%	1.17e-03	100.00%

TABLE 5.4
ARSENIC LIFETIME CANCER RISK LEVELS (ALL CANCERS) FOR HOME GARDEN CONSUMERS

	Cancer Risk Level				
	Deterministic		Probablistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario					
Typical Ontario Resident	1.42e-03	2.56e-04	3.19e-04	5.37e-04	8.17e-04
Deloro Alone					
Whole Town	4.09e-04	1.14e-04	6.57e-05	1.09e-04	1.79e-04
Zone 1	1.42e-04	8.37e-05	4.83e-06	8.15e-05	1.44e-04
Zone 2	1.75e-04	9.08e-05	5.42e-05	8.85e-05	1.55e-04
Zone 3	3.97e-04	1.25e-04	7.52e-05	1.34e-04	2.30e-04
Zone 4	4.89e-04	1.51e-04	7.84e-05	1.30e-04	2.06e-04
Deloro Including Background					
Whole Town	1.71e-03	3.51e-04	4.02e-04	6.27e-04	9.12e-04
Zone 1	1.44e-03	3.21e-04	3.74e-04	6.02e-04	8.86e-04
Zone 2	1.47e-03	3.28e-04	3.77e-04	6.11e-04	8.90e-04
Zone 3	1.69e-03	3.62e-04	4.28e-04	6.61e-04	9.40e-04
Zone 4	1.79e-03	3.89e-04	4.14e-04	6.41e-04	9.32e-04

TABLE 5.5
ARSENIC LIFETIME CANCER RISK LEVELS (ALL CANCERS) FOR NON-HOME GARDEN CONSUMERS

	Cancer Risk Level				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario					
Typical Ontario Resident	1.41e-03	2.53e-04	3.08e-04	5.39e-04	8.23e-04
Deloro Alone					
Whole Town	3.83e-04	1.07e-04	5.95e-05	9.84e-05	1.68e-04
Zone 1	1.39e-04	8.20e-05	4.76e-05	7.91e-05	1.43e-04
Zone 2	1.70e-04	8.79e-05	5.08e-05	8.42e-05	1.51e-04
Zone 3	3.77e-04	1.18e-04	6.82e-05	1.16e-04	1.99e-04
Zone 4	4.65e-04	1.38e-04	7.29e-05	1.16e-04	1.88e-04
Deloro Including Background					
Whole Town	1.68e-03	3.44e-04	3.84e-04	6.23e-04	9.08e-04
Zone 1	1.44e-03	3.19e-04	3.71e-04	5.95e-04	8.77e-04
Zone 2	1.47e-03	3.25e-04	3.76e-04	6.04e-04	8.83e-04
Zone 3	1.67e-03	3.53e-04	4.11e-04	6.36e-04	9.19e-04
Zone 4	1.76e-03	3.75e-04	4.13e-04	6.31e-04	9.19e-04

TABLE 5.6
INCREMENTAL ARSENIC LIFETIME CANCER RISK LEVELS (BY CANCER TYPE) FOR WHOLE TOWN

	Cancer Risk Level				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
All Cancers Combined					
Typical Ontario Resident	1 42e-03	2.56e-04	3.19e-04	5.37e-04	8.17e-04
Deloro alone (no home garden consumption)	3.83e-04	1.07e-04	5.95e-05	9.84e-05	1.68e-04
Deloro alone (home garden consumption included)	4.09e-04	1.14e-04	6.57e-05	1.09e-04	1.79e-04
Deloro including home garden consumption and background contribution	1.71e-03	3.51e-04	4.02e-04	6 27e-04	9.12e-04
Lung Cancers					
Typical Ontario Resident	2.81e-05	2.75e-06	2.94e-06	1 00e-05	1.89e-05
Deloro alone (no home garden consumption)	4.38e-07	1.75e-07	1 69e-07	3.76e-07	7.39e-07
Deloro alone (home garden consumption included)	4.38e-07	1.75e-07	1 69e-07	3.76e-07	7.39e-07
Deloro including home garden consumption and background contribution	3.94e-06	1.17e-06	1.04e-06	2.83e-06	5.28e-06
Skin Cancers					
Typical Ontario Resident	1.39e-03	2.53e-04	3.04e-04	5 20e-04	8.02e-04
Deloro alone (no home garden consumption)	3.83e-04	1.07e-04	3.93e-05	9.81e-05	1.68e-04
Deloro alone (home garden consumption included)	4.08e-04	1.14e-04	6.48e-05	1.07e-04	1.83e-04
Deloro including home garden consumption and background contribution	1.70e-03	3.50e-04	3.92e-04	6.14e-04	9.10e-04

Figure 5-2 Contribution of Various Pathways to Preschool Child Receptor Exposure to Arsenic (Probabilistic Mean)

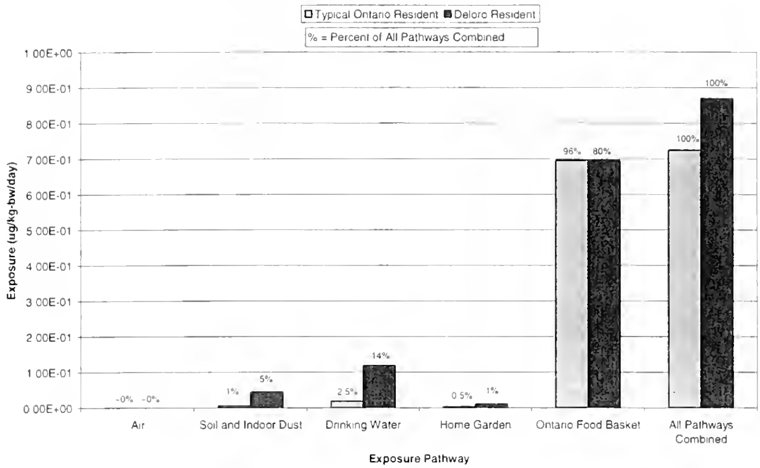


Figure 5-3 Contribution of Various Pathways to Adult Receptor Exposure to Arsenic (Probabilistic Mean)

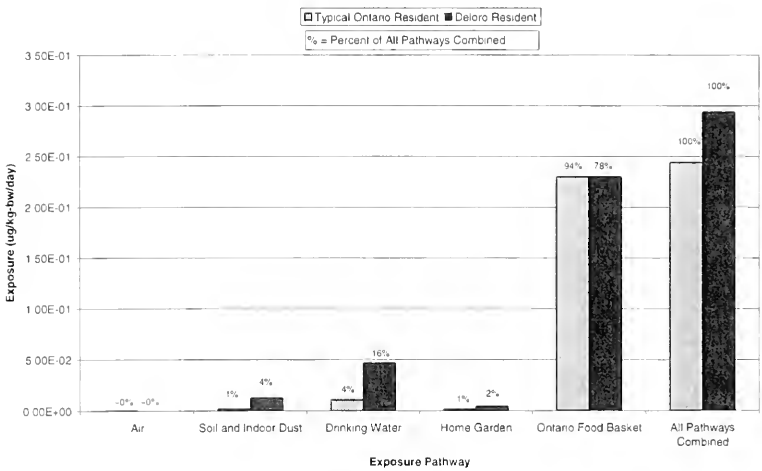
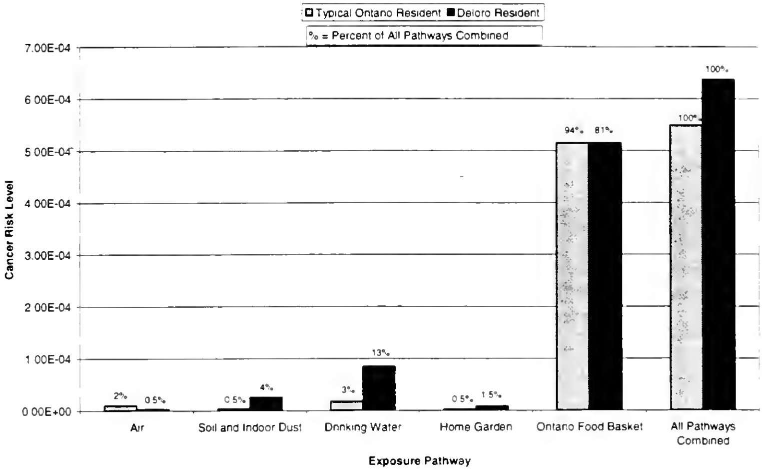


Figure 5-4 Contribution of Various Exposure Pathways to Lifetime Risk from Exposure to Arsenic (Probabilistic Mean)



based on an epidemiological study of skin cancer in a Taiwanese population, and limitations in using these data include uncertainties in actual exposure levels, nutritional status and other factors affecting susceptibility to toxicity. In the frame of reference of the current assessment, if the skin cancer potency of arsenic has been overestimated, then the risks of skin cancer predicted for the population of Deloro or Ontario would also have been overestimated in this assessment. Therefore, given that the same methodologies were used in estimating exposure and risk for typical Ontario residents and Deloro residents, the comparison of these two groups would be the most appropriate way of evaluating the risk estimates. Given that based on actual cancer risk estimates the typical Ontario resident is not considered to be at elevated risk of skin cancer from arsenic, the predicted risk for this population can provide a benchmark by which risks to Deloro residents may be evaluated, as has been done above.

The forecast charts shown in Figures 5-5 and 5-6 are examples of the probability density function (PDF) characterizing the distribution of CRLs for carcinogenic arsenic risks for the composite receptor of Deloro, following 10,000 iterations of the probabilistic model. The forecast chart demonstrates the actual shape of the distribution of risk estimates. PDFs for the other probabilistic modelling results (all receptors, arsenic and lead, home garden consumers and non-consumers) have a similar shape, as can be seen in comparing the distribution for Ontario and Deloro composite receptors. These results demonstrate that, for both Deloro and Ontario residents, the 95th percentile of risk estimate, which is typically used as the decision point in probabilistic risk estimates, is representative of only a very small segment of the population. In comparison, the risk estimates for the bulk of the population, which fall around the 50th percentile, tend to be much lower than the 95th percentile.

As would be expected, based on the discussion of results earlier, the cancer risk estimates for Ontario residents are slightly lower than those for Deloro residents, which is reflected in the minor shift of the typical Ontario distribution curve to the left.

FIGURE 5-5
PROBABILITY DISTRIBUTION FUNCTION FOR CARCINOGENIC ARSENIC RISKS FOR TYPICAL ONTARIO RESIDENT

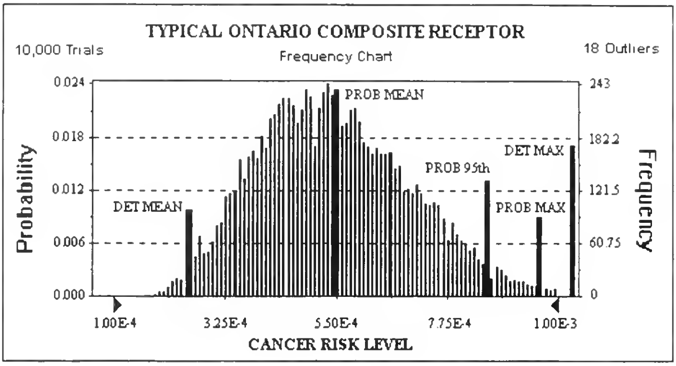
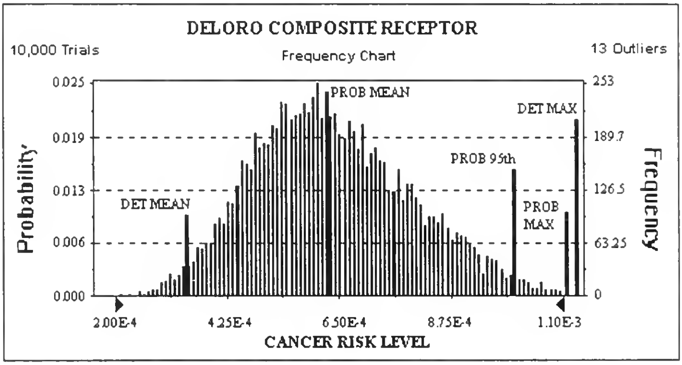


FIGURE 5-6
PROBABILITY DISTRIBUTION FUNCTION FOR CARCINOGENIC ARSENIC RISKS FOR DELORO RESIDENT



Arsenic (Non-Carcinogenic). The maximum deterministic exposure estimates for Deloro residents and typical Ontarians exceeded the toxicological criterion, which was based on adverse effects on the skin, with and without consumption of home garden produce (see Tables 5.7, 5.8, and 5.9). The highest estimated risk values were observed for infants and preschool children in Deloro [mean and maximum Exposure Radio (ER) values of 1.75 and 10.5 for preschool children without home garden consumption]. The estimates for typical Ontario residents of the same age classes were lower by a factor of 1.6-fold (mean and maximum ER values of 1.01 and 6.75 for preschool children). The observed ERs indicated marginal exceedences of the toxicological criterion; however, because there were exceedences, and because risk estimates for residents of Deloro exceeded those predicted for typical Ontario residents, arsenic was retained for probabilistic analysis based on non-carcinogenic endpoints.

TABLE 5.7
ARSENIC (NON-CARCINOGENIC) LONG-TERM EXPOSURE RATIO VALUES (PRESCHOOL CHILD) FOR HOME GARDEN CONSUMERS

	Exposure Ratio Values				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario					
Typical Ontario Resident	6.78	1.02	0.754	2.35	5.17
Deloro Alone					
Whole Town	3.63	0.639	0.203	0.516	1.23
Zone 1	1.29	0.44	1.98	2.21	2.84
Zone 2	1.58	0.487	0.157	0.397	1.06
Zone 3	3.53	0.707	0.256	0.657	1.59
Zone 4	4.36	0.878	0.262	0.65	1.47
Deloro Including Background					
Whole Town	10	1.57	1.16	2.89	5.73
Zone 1	7.66	1.37	1.01	2.72	5.42
Zone 2	7.96	1.41	1.05	2.77	5.5
Zone 3	9.9	1.64	1.23	3.06	5.87
Zone 4	10.7	1.81	1.24	3.03	5.81

TABLE 5.8
ARSENIC (NON-CARCINOGEN) LONG-TERM EXPOSURE RATIO VALUES (PRESCHOOL CHILD) FOR NON-HOME GARDEN CONSUMERS

	Exposure Ratio Values				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario					
Typical Ontario Resident	6.75	1.01	0.74	234	5.17
Deloro Alone					
Whole Town	3.4	0.608	0.182	0.471	1.18
Zone 1	1.26	0.433	1.98	2.21	2.83
Zone 2	1.54	0.474	0.148	0.394	1
Zone 3	3.35	0.668	0.232	0.592	1.49
Zone 4	4.13	0.826	0.233	0.564	1.39
Deloro Including Background					
Whole Town	9.78	1.54	1.13	2.86	5.7
Zone 1	76.3	1.36	0.972	2.62	5.42
Zone 2	7.91	1.4	1.02	2.66	5.66
Zone 3	9.73	1.6	1.18	2.97	5.8
Zone 4	10.5	1.75	1.21	2.95	5.67

TABLE 5.9
INCREMENTAL ARSENIC (NON-CARCINOGEN) LONG-TERM EXPOSURE RATIO VALUES (PRESCHOOL CHILD) FOR WHOLE TOWN

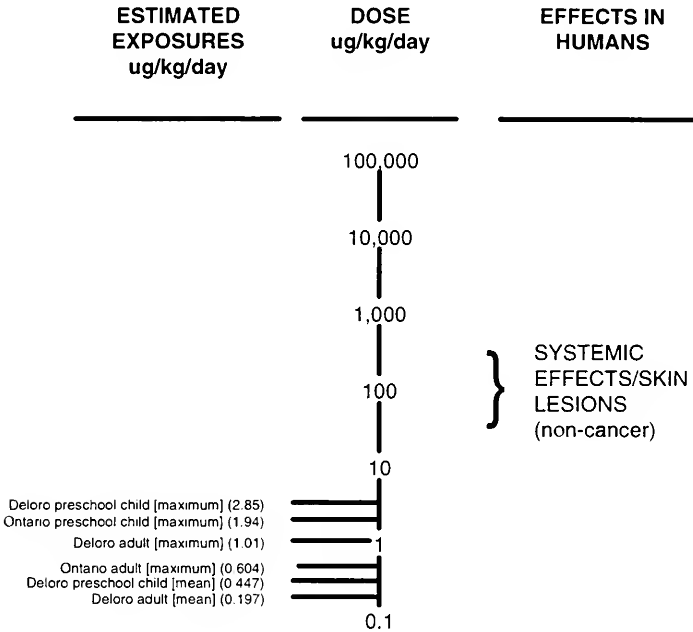
	Exposure Ratio Values				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario resident	6.78	1.02	0.754	2.35	5.17
Deloro alone (no home garden consumption)	3.4	0.608	0.182	0.471	1.18
Deloro alone (home garden consumption included)	3.63	0.639	0.203	0.516	1.23
Deloro including home garden consumption and background contribution	10	1.57	1.16	2.89	5.73

The probabilistic assessment indicated that the lower end of the range of exposures (5th percentile) for all typical Ontario receptors except the infant were less than the toxicological criterion, while the upper end (95th percentile) exposures for all typical Ontario receptors exceeded the toxicological criterion. In the absence of consumption of home garden produce, the 95th percentile ER values for Deloro residents were slightly elevated, by less than 0.2-fold, over that of typical Ontario residents (5.80 versus 5.17 for 95th percentiles for the preschool child). The toxicological criterion for the non-carcinogenic endpoints of arsenic, derived by the U.S. EPA, is based on adverse skin effects (hyperpigmentation, keratosis). Other regulatory agencies have derived criteria to be protective of the non-carcinogenic endpoints of arsenic. Health Canada, for example, has promulgated a guideline protective of induction of symptoms of chronic arsenic poisoning of 2 µg/kg bw/d, as compared to the U.S. EPA value of 0.3 µg/kg bw/d. Although the more conservative value was employed in the risk assessment, use of the Health Canada guideline in the risk assessment would have resulted in the estimation of exposures for both Deloro and Ontario residents that were at or below the toxicological criterion (with a 95th percentile of 0.87).

A graphical representation of the estimated exposures of Deloro residents in comparison to the range of doses observed to cause adverse non-cancer effects in humans is provided in Figure 5-7. The occurrence of systemic effects and/or skin lesions in human populations exposed to arsenic has been associated with exposure levels much higher than those predicted for Deloro residents.

Given the conservatism in the toxicological criterion, and given that the estimated risks to Deloro residents very marginally exceeded those for Ontario residents, it was concluded that there would be no unacceptable risks posed to Deloro residents from concentrations of arsenic within the village.

FIGURE 5-7
DOSES OBSERVED TO CAUSE NON-CANCER ADVERSE EFFECTS IN HUMANS VS. DELORO RELATED DOSES



adapted from: ATSDR, 1999. Agency for Toxic Substances and Disease Registry, Public Health Statement - Arsenic. http://www.atsdr.cdc.gov/ToxProfiles/phs8802.html

As in the assessment of arsenic on a carcinogenic basis, general food basket contributed a significant proportion of the overall risks to Deloro residents. While the major contributor to Deloro-specific risks was municipal drinking water, the concentrations in drinking water in Deloro were well below Ontario Drinking Water Objectives for safety. Dermal contact with soils/dusts and, for small children, ingestion of soils/dust were minor contributors to risk. With the consumption of home garden produce, ER values increased minimally for Deloro residents (less than 0.02-fold higher).

Cobalt. Both the mean and maximum plausible estimates of exposure for residents of Deloro (whole town, and for each zone) were less than the toxicological criterion (as indicated by ERs less than 1.0). This indicates that there would be no measurable risk of adverse health effects (polycythemia or metaplasia of the larynx). However, mean exposures for typical Ontario residents approached, and for the preschool child slightly exceeded, the toxicological criterion. The maximum typical Ontario exposures were slightly in exceedance of the toxicological criterion (up to about 3.5-fold for the preschool child). Thus, the exposure estimates for Deloro residents were less than the toxicological criterion, and risk estimates for Deloro residents were well below that for typical Ontarians, with and without the consumption of home garden produce. Therefore, based on the comparison to predicted risks for typical Ontario residents and the

comparison to the toxicological criterion, it was concluded that the exposures to cobalt associated with environmental media in Deloro would not be associated with measurable risks of adverse health effects.

Lead. Exposures of Deloro residents not consuming home garden produce only marginally exceeded the toxicological criterion, which was based on neurological effects in children, even at the plausible maximum. Except for the infant, mean exposure estimates for the age classes were less than the criterion (as indicated by ER values of 0.746 for preschool children), while plausible maximum values were up to 2.2-fold higher than the criterion. Similarly, mean typical Ontario exposures for all receptors were less than the toxicological criterion (ER of 0.867 for preschool children), although they were only marginally less for infants, while maximum estimated exposures ranged up to 2.44 times higher than the criterion (Table 5.10 and Figure 5-8). As can be interpreted from the ER values cited in Tables 5.11 and 5.12, without the consumption of home garden produce, maximum and mean neurotoxicity risk estimates for typical Ontario residents exceeded those for Deloro residents (by about 0.2-fold).

When potential exposures associated with consumption of home garden produce were assessed, increases in estimated exposures of Deloro residents were observed, with ERs of consumers up to about 2.5 times those of non-consumers. Mean exposure estimates exceeded the toxicological criterion only for preschool children, while maximum exposures exceeded the toxicological criterion for all age classes of Deloro residents (with ER values up to 5.86). The observed increase in exposure and risk was considered marginal; however, since exposures of home garden produce-consuming Deloro residents were greater than the toxicological criterion and typical Ontario exposures, risks associated with lead were more rigorously examined in the probabilistic assessment.

TABLE 5.10
LEAD LONG-TERM EXPOSURE RATIO VALUES (PRESCHOOL CHILD) FOR HOME GARDEN CONSUMERS

	Exposure Ratio Values				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario					
Typical Ontario Resident	2.55	0.913	0.764	1.01	1.6
Deloro Alone					
Whole Town	4.21	0.501	0.183	0.634	2.01
Zone 1	1.98	0.188	0.0788	0.276	0.868
Zone 2	1.8	0.251	0.131	0.62	2.2
Zone 3	5.08	0.742	0.262	1.01	3.28
Zone 4	2.48	0.454	0.202	0.508	1.28
Deloro Including Background					
Whole Town	5.07	1.17	0.759	1.28	2.62
Zone 1	2.8	0.814	0.692	0.908	1.53
Zone 2	2.37	0.852	0.749	1.25	2.85
Zone 3	5.86	1.34	0.881	1.64	3.94
Zone 4	3.26	1.05	0.811	1.14	1.93

Figure 5-8

Exposure Pathways Analysis (% of Risk) - Lead

[mean preschool child home garden consumer]

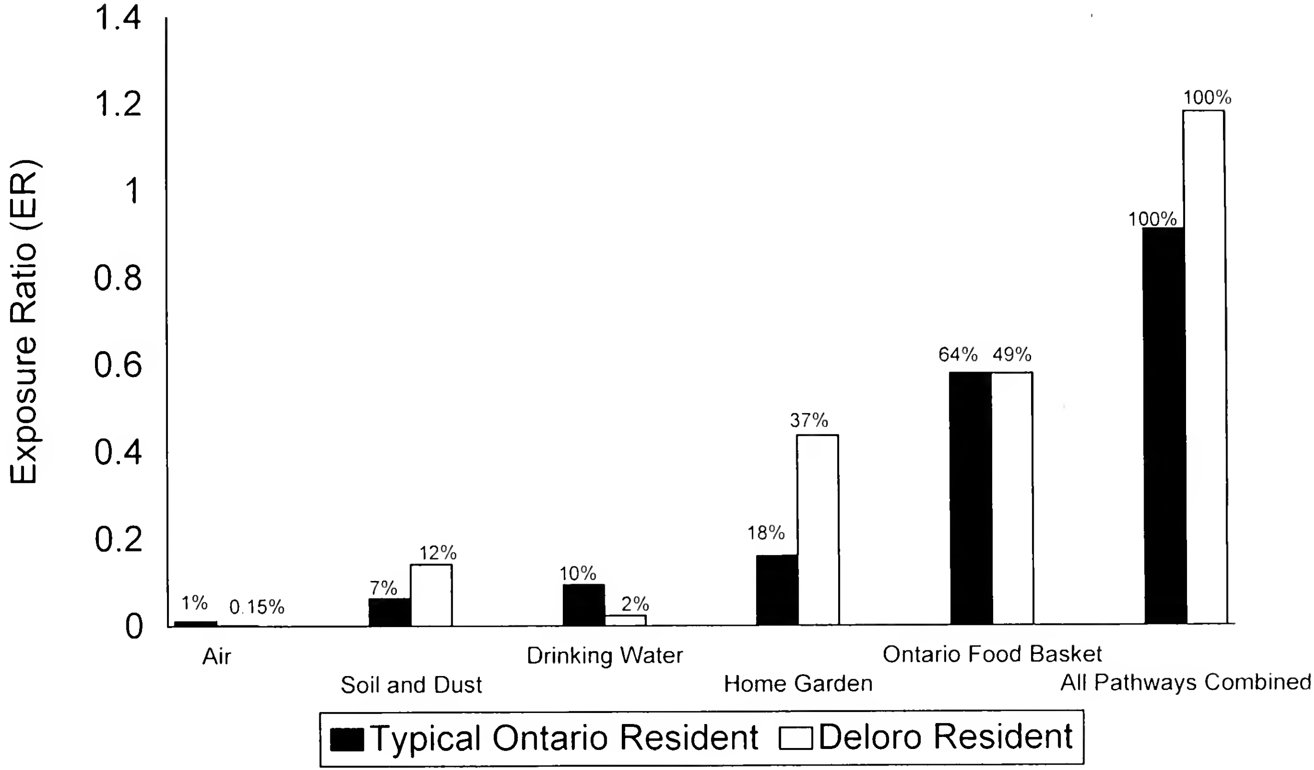


TABLE 5.11
LEAD LONG-TERM EXPOSURE RATIO VALUES (PRESCHOOL CHILD) FOR NON-HOME GARDEN CONSUMERS

	Exposure Ratio Values				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario					
Typical Ontario Resident	2.44	0.867	0.743	0.825	1.57
Deloro Alone					
Whole Town	1.21	0.146	0.0411	0.16	0.53
Zone 1	0.681	0.0605	0.0225	0.094	0.295
Zone 2	0.628	0.0695	0.0362	0.153	0.579
Zone 3	1.4	0.187	0.054	0.219	0.817
Zone 4	0.787	0.118	0.0394	0.136	0.397
Deloro Including Background					
Whole Town	1.99	0.746	0.643	0.788	1.21
Zone 1	1.46	0.661	0.625	0.723	0.978
Zone 2	1.4	0.67	0.641	0.783	1.26
Zone 3	2.17	0.787	0.657	0.848	1.5
Zone 4	1.56	0.718	0.639	0.798	1.08

TABLE 5.12
INCREMENTAL LEAD LONG-TERM EXPOSURE RATIO VALUES (PRESCHOOL CHILD) FOR WHOLE TOWN

	Exposure Ratio Values				
	Deterministic		Probabilistic		
	Plausible Maximum	Typical Average	5th Percentile	Median	95th Percentile
Typical Ontario Resident	2.55	0.913	0.764	1.01	1.6
Deloro alone (no home garden consumption)	1.21	0.146	0.0411	0.16	0.53
Deloro alone (home garden consumption included)	4.38	0.582	0.185	0.659	1.95
Deloro including home garden consumption and background contribution	5.16	1.18	0.8	1.29	2.59

In the probabilistic analysis, estimated exposures for typical Ontario infants, preschool children and children ranged from below the toxicological criterion for the 5th percentile results (ER of 0.764 for preschool children) to slightly in exceedence of the limit for the 95th percentile (ER of 1.6) (see Table 5.10). 5th and 95th percentile exposures for typical Ontario adolescents and adults were both less than the toxicological criterion. For Deloro residents, in the absence of exposure to lead through the consumption of home garden produce, the 5th and 95th percentile ERs were slightly less than those reported for typical Ontario exposures for all receptors except the infant (ERs of 0.643 and 1.21,

respectively, for preschool children). While 5th percentile ER values for the infant resident of Deloro Village were less than typical Ontario residents, the 95th percentile values for the infant for the whole town and, Zones 2 and 3 were marginally in exceedance of typical Ontario 95th percentiles. Further, these increments were slight, and were observed only for the infant, for whom a major contributor, soil/dust ingestion, was likely overestimated. Therefore, in the absence of consumption of home garden produce, exposures to lead in environmental media within Deloro were not considered to increase overall risks of residents, and would not be associated with a measurable increase in risks of neurological effects.

The major contributors to the risks to typical Ontario residents associated with lead were the general food basket and, to a lesser extent, drinking water. The contributors to overall risks for residents of Deloro indicated that the significance of contribution due to various exposure pathways was greatly dependent on receptor characteristics. Reviewing the predicted exposures in the absence of consumption of home garden produce, soil/dust ingestion contributed 45 to 60 percent of maximum risks for the infant and preschool child, and 20 to 25 percent of the mean risks, respectively. Again without home garden consumption, these pathways contributed 16 and about 2 percent of the maximum and mean overall risks for adults. Contributions to mean exposure via the general food basket ranged from about 71 percent for infants and preschool children to 90 percent for adults, while general food basket contributed about 25 and 50 percent to maximum exposures, for children and adults, respectively. Drinking water consumption provided a significant pathway of exposure (without home garden) as well, with consumption of Deloro municipal water contributing 10 to 20 percent of the maximum, and 1 to 2 percent of the mean risks for all receptors. Similar but lower contributions were made by consumption of water from Ontario sources. The greater contribution to exposure to lead in drinking water from Deloro was due to the greater daily consumption within Deloro, as concentrations in Deloro municipal water were one fourth to one seventh of the values report for Ontario drinking water. As shown in Figure 5-8, the consumption of home garden produce contributed about 40 percent of the overall mean risks to Deloro residents (about 70% of maximum risks). Other pathways correspondingly decreased in proportional contribution, with general food basket about 50 percent, soil/dust pathways about 10 percent, and drinking water about 2 percent of the overall risks.

The maximum probabilistic ER value for Deloro residents consuming home garden produce was 3.94. Although this is indicative of exposures exceeding the criterion based on neurological effects, an exceedance of this magnitude was not considered to be of concern, given the conservatism inherent in this risk assessment. The toxicological criterion is based on the lowest effective blood lead level reported in epidemiological studies of the effects of lead in human infants, who are considered to be the most sensitive receptors, based on both their susceptibility to neurodevelopmental effects as well as their higher gastrointestinal absorption of lead. In addition, the estimation of risks specifically to consumers of home garden produce was considered to be conservative for several reasons. These include the use of the entire range of concentrations throughout Deloro in the estimation of exposure included concentrations, not just those in back yards and gardens. Because home garden produce is more likely grown in these areas, which had lower concentrations, actual exposures and risks are expected to be lower. Based on this overestimation and on the minimal increase in risks, the exposures

to lead from consumption of home garden produce is not expected to measurably increase risks to Deloro residents.

To put the surface soil concentrations of lead in Deloro into perspective, they were compared to concentrations found elsewhere in Ontario. Lead concentrations in Deloro surface soil were found to be in general agreement with the reported concentrations in urban soils (average 123 mg/kg, maximum 845 mg/kg for urban Ontario soils, as compared to 121 and 655 mg/kg for the average and maximum in Deloro soils). The importance of exposure to lead via direct soil pathways to overall risks of typical Ontario residents was re-examined based on the acceptable blood lead level (PbB) of 10 µg/dL, and studies of and models describing the relationship between PbB and exposure via all relevant exposure pathways. Several agencies, including the Centers for Disease Control and the U.S. EPA, have indicated a necessity for soil concentrations greater than 500 to 1,000 mg/kg before blood lead levels in children would be greater than typical background levels. In its Scientific Criteria Documents (1994), the MOE investigated several models of environmental exposure to lead. These included the Integrated Uptake/Biokinetic Model (IU/BK), which calculates PbB based on environmental media concentrations, and the Society for Environmental Geochemistry and Health Model (SEGH), which relates soil concentrations to PbB. The results of both models, as cited by the MOE, indicate that (in agreement with the CDC and U.S. EPA findings) soil concentrations would have to exceed 600 and 855 mg/kg, based on the IU/BK and SEGH models respectively, before blood lead levels of children would exceed the acceptable PbB of 10 µg/dL. This further supports the conclusion of the current assessment that concentrations of lead in Deloro soils would have no measurable impact on overall exposure and risk of Deloro residents.

Nickel. The mean and maximum exposures determined for nickel, with and without consumption of home garden produce, were elevated above the toxicological criterion for exposures associated with typical Ontario, whole town, and each of the zones. The ERs for overall exposure of Deloro residents were much less than those for exposures of a typical Ontario resident, and, indeed, the majority of risks predicted for Deloro residents were derived from exposures not associated specifically with the town (i.e. the general food basket). Given that mean and maximum typical Ontario risks exceeded the risks predicted for Deloro residents, and that the majority of the risk indicated for Deloro residents was contributed by general food basket common to all Ontario residents, concentrations of nickel in Deloro environmental media were not considered to pose an increased risk of adverse health effects, in comparison to typical Ontario.

Silver. With and without the consumption of home garden produce, mean and maximum exposures for the whole town and each of the zones were less than the toxicological criterion (based on induction of argyria) for all receptors except the infant and the preschool child (as indicated by ERs less than 1.0). For the infant, both mean and maximum exposures slightly exceeded the toxicological criterion, while only the maximum exposure for the preschool child exceeded the toxicological criterion. Argyria risk estimates for Deloro residents were slightly greater than those calculated for exposures of a typical resident of Ontario. It was concluded that concentrations of silver in environmental media in the Village of Deloro would not result in a measurable increase in risk of adverse health effects for the following reasons:

- The toxicological criterion for silver is based on the induction of argyria, which is a strictly cosmetic alteration of colouring that is not associated with any type of tissue damage or actual adverse health effect
- The contributions to risk not associated with Deloro are based mainly on a highly conservative estimate of intake via general food basket, especially for infants and children, and, as such, comprised a high proportion of the total risk
- The exceedance of the toxicological criterion was marginal

Relevance of Exposures via Soil and Dust

The significance of contamination in indoor dust and outdoor soils and dusts within Deloro to the exposure and risk of its residents varied for each of the chemicals of concern. Direct exposure pathways for soil and dusts include accidental ingestion of soils or dust, inhalation of airborne particles, and dermal contact with soils. An indirect pathway of exposure to contaminants in soils, consumption of fruits and vegetables grown in home gardens, is discussed separately below.

For cobalt, nickel and silver, the ingestion, inhalation and dermal exposure via indoor and outdoor soil/dust contributed relatively minor proportions of overall risks of Deloro residents who also consumed home garden produce.

For lead, direct exposure pathways for soils and dusts contributed a higher proportion to overall risks of Deloro residents (11 to 18% for preschool children). However, overall exposures of Deloro residents, in the absence of home garden consumption, were less than that of Ontario residents, thus contributions of direct soil and dust exposure pathways to exposure would not measurably increase risk to Deloro residents. Therefore, it was concluded that since soils in Deloro do not measurably increase risk of adverse health effects, no remedial activity is required.

The deterministic analysis indicated that exposure to arsenic via direct pathways comprised a significant proportion of overall risk for Deloro residents. Children experienced relatively higher exposures via soil ingestion (contributing about 10% to overall deterministic risks) than did adults (contributing 2%). Contribution to overall risk by exposure via dermal contact was similar in both children and adults (5 to 25% and 10 to 20%, respectively, for mean and maximum deterministic estimates).

The importance of examining specific environmental media with respect to impacts on the overall risks for Deloro residents lies in the utilization of such information to guide risk management decisions. Since exposure pathways for soil/dust was identified in the deterministic analysis as a contributor to overall risk for arsenic, for both children and adults residing in Deloro, the importance of these pathways to risk estimation in the more rigorous probabilistic analysis was also evaluated. This allowed the incorporation of the more realistic modelling of the probabilistic analysis in development of risk management recommendations for the two metals considered to be of potential concern.

In theoretical probabilistic modelling, it was determined that cessation of direct exposure to soils and dusts (i.e. ingestion, inhalation or dermal contact with indoor and outdoor soils/dust), would result in only a 2 to 4 percent reduction (for 95th and 5th percentiles, respectively) in the overall risks for the composite receptor. Therefore, it can

be concluded that even if concentrations of arsenic in soils and dusts were reduced to equal typical Ontario concentrations, there would be no measurable reduction of exposure, based on direct contact pathways.

In conclusion, the results of the probabilistic analysis indicated that the exposures to Deloro residents to arsenic and lead in soils and dusts via direct contact pathways (ingestion, inhalation, and dermal contact) were not of sufficient significance to require remediation of soils and dusts. The impact of such remediation on overall risks would be negligible, and would not result in any measurable decrease in predicted risks.

Relevance of Consumption of Home Garden Produce

The contribution of the consumption of home garden produce grown in Deloro to estimates of overall risks varied considerably with the chemical under examination. While the deterministic analysis indicated that contribution of home garden produce to overall risks associated with cobalt was less than 2 percent, risks from the consumption of home garden produce contributed approximately 60 to 70 percent of the maximum and 30 to 40 percent of the mean overall risks for lead. Intermediate contributions of home garden produce consumption are indicated for the other metals, such as arsenic, for which home garden contributed about 10% of the predicted deterministic risks. Examination of the components of home garden produce responsible for the observed exposures indicated that for lead, vegetables (especially root vegetables) contributed about 80 percent of the home garden exposure.

Given that exposures through the consumption of home garden produce were negligible for most of the metals, and that the marginal increase in overall risks for lead for Deloro residents in comparison to typical Ontario residents, it was concluded that the use of the home garden did not measurably increase risks to Deloro residents, and did not require remediation.

Relevance of Exposures via Trespassing on the Mine Site

The trespasser scenario completed by CANTOX evaluated the risk of exposure to arsenic, cobalt, lead, nickel, and silver while a resident of Deloro trespassed on the mine site. The chemicals boron, beryllium, cadmium, copper, and mercury are also present on the mine site; the risks associated with exposure to these metals are discussed in Appendix F.

In general, only for maximum risk estimates for arsenic (carcinogenic and non-carcinogenic endpoint) were there significant increases in the CRL/ER values following addition of the trespasser scenario. Contributions of trespasser exposures to mean predicted risks for arsenic were minimal, and the contributions of the trespasser scenario to mean and maximum risks for cobalt, lead, nickel, and silver were negligible. It was concluded that the results for the trespasser scenario likely overestimated risks to Deloro residents by a significant degree, especially for arsenic. For example, there are concerns about the validity of the use of the maximum concentrations of arsenic reported for the mine site, given the unlikelihood that a resident hiking on the mine site would spend any prolonged period of time in contact with these areas of extreme concentrations. Additionally, the trespasser scenario considered direct contact soil related exposure pathways similar to those considered for the town, while it is expected that people will only spend time walking on the mine site. It was concluded that the

trespassing on the mine property may contribute significantly to the overall risks of Deloro residents, and therefore mitigation of this exposure (e.g. through limited access) should be considered in development of the remediation plan for the site.

U.S. EPA Urinary Arsenic Model Evaluation

A non-parametric statistical test revealed there were no significant differences of total and speciated urinary arsenic levels between residents in Deloro Village (on a whole town basis, as well as for each of the four zones) and residents in Havelock. The measured urinary arsenic concentrations were also compared to concentrations reported in the published literature. The mean urinary arsenic concentrations of residents from both Deloro and Havelock fall in the range of typical Ontario areas, and are much less than the means reported for persons exposed to point sources of arsenic (such as mining/smelting, occupational, etc.).

In order to validate the exposure and urinary arsenic modelling, the measured values were also compared to predicted concentrations. The results of the urinary arsenic model were generally in good agreement with the measured concentrations in Deloro and Havelock. The slight overestimation of urinary arsenic concentrations indicates that the exposure assessment modelling was based on conservative values and assumptions, and that therefore the risk characterization is also conservative.

Uncertainty and Sensitivity Analysis

As part of the current assessment, a sensitivity analysis was conducted to identify the variables to which the risk characterization was most sensitive. It was observed that the variables to which the assessment was sensitive were model parameters that were considered to be realistic and conservative in nature. As such, there was confidence that the risk characterization results were accordingly realistic and conservative.

Several uncertainties were identified throughout the course of the assessment, in the following general areas:

- Environmental media concentrations (e.g. regarding concentrations less than detection in municipal well water, extrapolation of vegetable biotransfer factors from garden test plots to the entire village and validity of the extrapolation to fruits, extrapolation of indoor air concentrations from outdoor air, validity of exposure via general food basket common to all Ontarians).

- Biomonitoring analytical results (i.e. a large number of speciated urinary arsenic samples were less than the detection limit, which introduces some uncertainty only into the validation of the urinary arsenic model).

- Receptor physiological and behavioural parameters (e.g. the amount of time a receptor may spend on the abandoned mine site; soil ingestion by infants; intake of home garden produce; urinary volumes).

- Toxicological criterion derivations (e.g. use of most conservative toxicological criterion, humans were assumed to be the most sensitive species, conservatism was introduced by applying large uncertainty factors to limits for chemicals with threshold-type dose-responses). In the case of arsenic, there are concerns that the

oral cancer potency for arsenic based on exposures of Taiwanese populations to arsenic in drinking water may significantly overestimate skin cancer risks at lower exposure levels more representative of those experienced by the general North American population.

Given the above, this risk assessment may overestimate actual risks by a considerable degree, but will not underestimate potential health risks. However, due to the relatively large database of site specific information and the comprehensive nature of the probabilistic component of this assessment, this overestimation is not expected to be unduly unrealistic.

Conclusions

Everyone in Ontario is exposed to arsenic, lead, and other metals, and has a certain level of risk. This is because trace elements like arsenic are present in our environments wherever we live. When people living anywhere are exposed to arsenic, the greatest potential health risk is the development of skin cancer and, to a lesser degree, lung cancer. Studies elsewhere have also shown that high arsenic exposures are associated with internal cancers such as bladder cancer.

Exposure and risk estimates for Deloro residents were compared to the exposure and risk estimates for typical Ontario adults and children and it was found that overall exposures to arsenic were only marginally greater for Deloro.

- Estimated arsenic exposures are not measurably higher than those of typical Ontario residents.

- Overall exposures and risks for arsenic were only slightly greater when compared to estimates for the typical Ontario resident. For example, predicted maximum cancer risk (99th percentile) for arsenic in Deloro from all pathways totalled was less than 0.2 times higher than the mean risk for typical Ontario exposure (1.17 per 1,000 for Deloro versus 0.963 per 1,000 for Ontario). Most importantly the percent contribution of exposure or dose from soil and dusts (dermal, ingestion and inhalation) was small when compared to arsenic in the normal daily diet. The presence of arsenic in the Ontario diet is due to its natural occurrence as a trace element in the earth and its uptake into crops. There are also various forms of arsenic in food, which are considered non-toxic or less toxic than other forms.

- Predicted cancer and non-cancer risk levels were only slightly higher for Deloro residents than for individuals living elsewhere in Ontario. For example, it was estimated that roughly 80 percent of lifetime risks from exposure to arsenic in Deloro is from the normal Ontario food basket as compared to roughly 4 percent for soil and indoor dust combined. The relative contribution of specific pathways to total lifetime risk (e.g. backyard vegetables, diet, and soil) is shown in Figure 5-4. The combined risk from soil, indoor dust and home garden produce is one tenth that of the regular Ontario food basket. Furthermore, the levels of risk for each of the soil and indoor dust, and backyard vegetable pathways were found to be in the range that is considered negligible.

- If all soils in Deloro were replaced with background soils, overall risks from arsenic would be reduced by only 2 to 4 percent.

- Deloro residents would not experience risks from exposure to lead that were significantly greater than typical Ontario residents. No adverse health effects would be expected to occur at the levels of lead found in the village, as these levels were not unusually high.
- Levels of cobalt and silver in the village of Deloro are not high enough to result in any measurable health risk. Risks from exposure to nickel in Deloro were comparable to typical Ontario residents.
- The levels of contaminants in drinking water were all well below Ontario Drinking Water Objectives for safety.

Task VI – Exposure Assessment and Health Risk Characterization for Radionuclides, Gamma Radiation, and Radon

SENES Consultants Limited (SENES) were retained to conduct an exposure assessment and health risk characterization for the residents of the Village of Deloro, based on measured and estimated environmental parameters including radon gas, terrestrial gamma radiation levels, and several radionuclides in the uranium decay series. The main objectives of the present assessment were to estimate the potential radiological doses and consequent risks to people living in the Village of Deloro. The potential doses and risks from natural background radioactivity were also estimated to provide a context for discussing the potential requirements for reducing radiation exposures, if considered necessary. This section summarizes the work completed by SENES in the final report entitled Radiological Health Risk Assessment for the Village of Deloro, July 1999.

General Methodology for Radiological Health Risk Assessment

The general methodology used for the health risk assessment consists of five phases: Phase I – Problem Formulation; Phase II – Exposure Assessment; Phase III – Hazard Assessment; Phase IV – Risk Characterization; and Phase V – Risk Management. In performing radiological risk assessments, the radiation doses via all potentially significant exposure pathways are estimated and summed to arrive at the total radiation dose to the receptors (people) under consideration. The resultant doses are then multiplied by appropriate risk factors to estimate the resultant risks. These tasks require the characterization of the site under study to address the nature and extent of the contamination relative to potential exposure of receptors; the identification of the contaminants of concern; the identification of potential receptors who are most likely to receive the greatest exposures; and the identification of the potential exposure pathways by which the various receptors are exposed to the contaminants under study.

Phase I: Problem Formulation

The village characteristics and study areas (4 zones) are as described in Section 1. The source of the above-background levels of radiation and radioactivity at the former Deloro Mine Site were the uranium and radium (Ra-226) residues from the uranium

refinery in Port Hope. This study specifically addressed potential exposures to the longer-lived radionuclides in the U-238 series, namely, U-238, U-234, Th-230, Ra-226, Pb-210, and Po-210. Exposure to radon was also evaluated. Potential exposures to natural thorium were not considered relevant to this study.

Pathways by which the residents of Deloro could be exposed and that were evaluated in this study included external (to the body) gamma radiation indoors and outdoors; inhalation of radon progeny indoors and outdoors; ingestion of home-garden produce; inhalation of airborne dust indoors and outdoors; and ingestion of dust/soil indoors and outdoors.

The analyses in this study were undertaken to cover the entire range of ages of residents in Deloro, and specific analyses were undertaken for the following age groups: 1- year-old (from 1 yr to 2 yr); 5-year-old (more than 2 yr to 7 yr); 10-year-old (more than 7 yr to 12 yr); 15-year-old (more than 12 yr to 17 yr); and adult (more than 17 yr).

These age groups are marginally different than the age groups considered for the metals health risk assessment. They were chosen because of the availability, from the International Commission on Radiological Protection (ICRP), of age-dependent dose conversion factors for these specific ages. The ICRP (Publication 72, 1996) considers that the age-specific dose factors for each age group can be applied to the ranges of ages noted above. As with the metals health risk assessment, the Canadian human exposure factors published by Richardson (1997) were used to obtain exposure and consumption values, if available. The age-dependent parameter values and estimated doses and risks in this assessment were considered to apply to both males and females.

Phase II: Exposure Assessment

The following general protocol was used to obtain information (data) for exposure factors used in the exposure pathways analyzed. As recommended by the MOE, the first source used to obtain exposure factors for this study was Canadian data compiled by Richardson (1997). In the absence of any Canadian data, studies summarized by the U.S. EPA were used because of similarities between the U.S. and Canadian populations.

For deterministic calculations, the arithmetic mean of the data was used as the typical mean. A plausible maximum was calculated based on the 95th percentile of the data distribution. If published distributions that described the data were available, they were used in the assessment.

The specific input data and distributions selected for the assessment are provided in the complete SENES report.

Phase III: Hazard Assessment

In this assessment, the radiation doses from both internal (to the body) and external exposures via all potentially significant exposure pathways were estimated and summed to arrive at the total radiation dose to the receptors (people) under consideration. The resultant doses were then multiplied by appropriate risk factors to estimate the resultant risks. This section summarizes the more detailed description of factors used by SENES as described in the study.

Internal Exposure Dose Conversion Factors. The inhalation and ingestion Dose Conversion Factors (DCFs) used in this assessment are taken from Publication 72 of the International Commission on Radiological Protection (ICRP 1996). The general recommendations of the ICRP on radiation protection issues (ICRP Publication 60, 1991), including the ICRP DCFs, are widely accepted and used in many countries, including in Canada by Health Canada, the Atomic Energy Control Board, and other federal and provincial agencies.

Radon. The inhalation of radon and its progeny is a special case. The potential risks from exposure to radon are actually associated with its short-lived decay products. Radon progeny typically contribute 50 percent or more of natural background radiation doses. Exposure to radon progeny is measured in terms of working level months (WLM), where 1 WLM is the exposure to 1 working level (WL) of radon progeny for 170 hours (defined as a working month). The WL is a measure of the concentration of radon progeny in air and is equivalent to a concentration of approximately 3,700 Bq/m^3 of radon in radioactive equilibrium with its progeny. The radon measurements in Deloro refer to total radon, comprising both background radon and any radon emitted from the Deloro site and any contaminated soils in the area.

The ICRP (1993) dose conversion factor for members of the public is

$$1\ WLM = 4\ mSv$$

This ICRP-recommended value was used in this assessment for estimating the doses to all age groups resulting from exposure to radon and its progeny.

External Exposure. External exposure in this assessment refers to gamma radiation exposure. External exposures by alpha and beta particles irradiate only the skin, not the more radiation-sensitive internal body organs.

Risk Conversion Factors. The ICRP (1991) has derived nominal values of risk to be used for radiation exposures of both workers and members of the public. The risk factors apply to low-dose rate exposures such as are relevant to the present study.

Phase IV: Risk Characterization

In considering the results of this analysis, it is important to remember that radioactivity and radiation is ubiquitous. Exposure to radiation and radioactivity is a part of our everyday life and unavoidable. Thus, for exposure to radiation and radioactivity, comparison to natural background levels of radiation and radioactivity provides a useful context. The probabilistic risk assessment produced distributions of doses and risks for both Deloro-specific concentrations and the estimated range of natural background for geologically similar areas in Ontario. The mean or average value from the probabilistic assessments provides the estimated total dose or risk, while the 95th percentile value provides an estimate of the maximum likely risk or dose.

Based on the results of this study, the radiological doses and lifetime risks predicted for current residents of the Village of Deloro are comparable to and within the range of doses and risks for Ontario residents from natural background radioactivity.

Annual Dose Results. The estimated annual doses are provided in Table 5.13. On an annual basis, the estimated annual radiation dose to an adult living in Deloro, including both

natural background for the area and the incremental contribution attributable to the mine site, was estimated at about 1.2 mSv/yr, as compared to 1.1 mSv/yr estimated for typical background exposures. The corresponding maximum likely dose for the adult (maximum likely dose is taken as the 95th percentile) was about 2.9 mSv/yr from natural background as compared to 2.7 mSv/yr for a Deloro resident. These ranges are shown in Figure 5-9. The average dose to a one-year-old was estimated at about 1.5 mSv/yr as compared to 1.4 mSv/yr estimated for natural background conditions. The corresponding maximum likely dose (i.e. the 95th percentile) to a one-year-old was estimated at about 3.7 mSv/yr from natural background conditions compared to about 3.3 mSv/yr, for a Deloro resident.

TABLE 5.13
ESTIMATED ANNUAL RADIOLOGICAL DOSES FOR ADULTS

Location	Total Mean Dose (mSv/y)	Mean Gamma Radiation Dose (mSv/y)	Mean Radon Dose (mSv/y)	95th Percentile of Total Dose (mSv/y)
Background	1.1	0.16	0.81	2.9
Deloro Village	1.2	0.2	0.85	2.7
Zone 1 (furthest from the mine site)	1.6	0.18	1.3	3.8
Zone 2	1	0.18	0.67	2.2
Zone 3	1	0.2	0.72	2.3
Zone 4 (nearest to the mine site)	2.7	0.23	2.3	6.3

Lifetime Risk Results. The estimated lifetime risk results are provided in Table 5.14. Lifetime risks are, in essence, the risks that accrue to an individual who spends his or her entire life in Deloro. This is done by calculating the annual dose in each life stage and multipying by the number of years in the life stage and in turn multiplying by age-dependent factors to convert dose to risk over remaining years of life. The lifetime risk is then estimated by summing the risks estimated for each life stage. Estimates of lifetime risk from a lifetime of exposure were calculated for Deloro and natural background conditions. Since dose and risk are directly related, the estimated risks from radiation were similar for residents of Deloro as they would be for someone exposed to natural background radiation. The mean value for lifetime risk from exposure to natural background was about 6.2 per 1,000 over a lifetime as compared to 6.6 per 1,000 for typical Deloro conditions. The maximum likely lifetime radiological risk from natural conditions was estimated to be about 1.6 per 100 and this value is slightly higher than the maximum likely risk, 1.5 per 100, estimated for Deloro conditions.

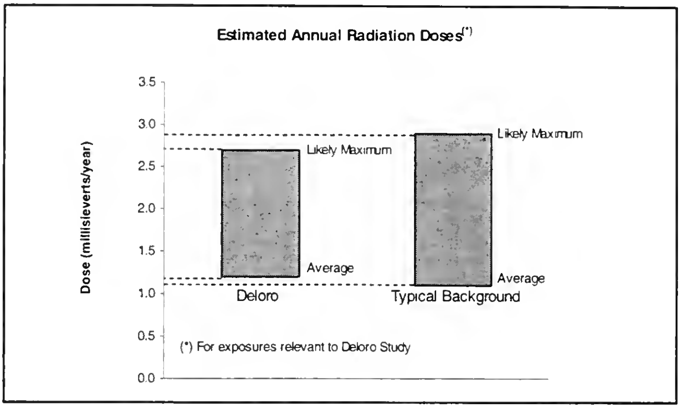
Trespasser Scenario Risk Results. Some Deloro residents occasionally spend time on the mine site itself and there is potential for above-background radiological risk from these activities. This exposure scenario is highly dependent on individual habits that are not necessarily reflective of general exposure conditions within Deloro itself, which is the prime focus of this study.

Gamma radiation fields averaged 74 and 109 μR/h in the Industrial and Young's Creek Areas, respectively. The overall average gamma radiation level was 91 μR/h based on the assumption of equal time spent in both areas. This radiation level is about 15 times higher than the typical radiation levels measured outdoors in the Village of Deloro.

TABLE 5.14
SUMMARY: PROBABILISTIC ESTIMATES OF LIFETIME RISK

Location	Gamma		Radon		Water		Other		Total	
	Mean (% of Total)	95th	Mean (% of Total)	95th	Mean (% of Total)	95th	Mean (% of Total)	95th	Mean	95th
All Deloro	1.1E-03 (17%)	1.5E-03	4.7E-03 (70%)	1.3E-02	7.4E-04 (11%)	1.6E-03	6.9E-05 (1%)	1.5E-04	6.6E-03	1.5E-02
Zone 1	1.1E-03 (12%)	1.4E-03	7.0E-03 (79%)	1.9E-02	7.4E-04 (8%)	1.6E-03	5.8E-05 (1%)	1.3E-04	8.8E-03	2.1E-02
Zone 2	1.1E-03 (19%)	1.3E-03	3.7E-03 (66%)	9.4E-03	7.3E-04 (13%)	1.5E-03	7.0E-05 (1%)	1.5E-04	5.5E-03	1.1E-02
Zone 3	1.2E-03 (20%)	1.5E-03	4.0E-03 (66%)	1.1E-02	7.5E-04 (13%)	1.6E-03	7.3E-05 (1%)	1.6E-04	6.0E-03	1.3E-02
Zone 4	1.3E-03 (9%)	1.5E-03	1.3E-02 (85%)	3.2E-02	7.4E-04 (5%)	1.6E-03	7.6E-05 (1%)	1.9E-04	1.5E-02	3.5E-02
Background	9.5E-04 (15%)	1.2E-03	4.4E-03 (71%)	1.5E-02	7.4E-04 (12%)	1.5E-03	1.0E-04 (2%)	1.7E-04	6.2E-03	1.6E-02

FIGURE 5-9
ESTIMATED ANNUAL RADIATION DOSES FOR DELORO RESIDENT AND TYPICAL BACKGROUND



The risk to Deloro residents from a lifetime of periodic casual access to the former Deloro Mine Site was about 3.0 E-04, which is less than about 5 percent of the mean risks estimated for the average Deloro resident.

Discussion of Risk Results. The major contributor to lifetime risk was radon, which accounted for about 70 percent of the average lifetime risk for Deloro conditions. Gamma radiation and water ingestion accounted for about 17 percent and 11 percent of the mean lifetime risk, respectively. The estimated risk from water ingestion is highly uncertain and in all likelihood an overestimate since the risk is driven by the laboratory detection limits (the water concentrations were below the detection limit; however the concentrations were assumed to range up to the detection limit for the risk assessment). The drinking water pathway assumes the same uncertainty for all zones including natural background and, therefore, the doses from this pathway are identical for the Deloro resident and a person exposed to natural background conditions. Risk from inhalation of airborne dust and ingestion of soil, dust, vegetables, and fruit accounted for only 1 percent of the total lifetime risk.

Sensitivity analysis indicated that the lifetime risk estimates were most sensitive to variability in the indoor radon concentrations. The variability in indoor radon concentrations explained more than 95 percent of the overall variability in the lifetime risk. Typically, the variation explained by each of the other input factors was less than 1 percent.

Although the estimated doses and consequent risks for residents of the village overall are comparable to the range of those from natural background, there is nonetheless an indication that there is a gradient in dose and risk from gamma radiation, with dose and risk decreasing with increasing distance from the mine site, the major contributor to the potential gradient is the relative elevation in levels close to the mine site that are attributable to radiation contamination on the mine site. It is possible that some gamma radiation may arise from contaminated materials located offsite. The distribution of natural mineralization may also be a factor in the observed gradient.

With respect to radon, elevated outdoor radon levels were observed near the site fence and therefore, for the area closest to the mine site, there is a possibility of some small elevation in the radon levels that could be attributed to site contamination. Radon doses are dominated by indoor levels, and radon doses were highest in the nearest and furthest zones from the site. It must be emphasized, however, that natural background levels of radon are highly variable and would naturally vary widely from home to home even in the absence of radioactive contamination. The highest radon values are not unusual in a geological formation in which mineralization is found. There is no indication that any radon levels are enhanced as a result of human activities in the area.

Although residents of Deloro do not appear to be exposed to levels of radiation and radioactivity above those from the typical range or background, there is a suggestion that close to the mine site the radiation levels may be elevated relative to those further away. Thus, consistent with the radiation protection principle that doses from man-related radiation should be as kept as low as reasonably achievable, social and economic factors taken into account (ALARA), some practical measures to reduce radiation risks could be examined.

Phase V: Risk Management

Combined Arsenic and Radiological Risk Results. The 95th percentile lifetime cancer risk level (CRL) due to arsenic exposure for a resident considering the whole town on average (Deloro alone) who consumes home-garden produce (all cancers combined) was 1.82 E-04. The lung cancer risk proportion of this total cancer risk was 7.14E-07.

The mean values for lifetime risk from exposure to natural background was about 6.2-E-3 as compared to 6.6-E-3 for typical Deloro conditions. The maximum likely lifetime radiological risk 95th percentile from natural conditions was estimated to be about 1.6-E-2 and this value is higher than the maximum likely risk, 1.5-E-2, estimated for Deloro conditions.

The major contributor to lifetime radiological risk was radon, which accounted for 70 percent of the average lifetime risk for Deloro conditions.

The only known health impact associated with exposures to elevated levels of airborne radon progeny is lung cancer. Therefore, the estimated lifetime risks associated with radon progeny exposures in Deloro can be considered attributable to the risk of lung cancer. For gamma radiation, which irradiates the whole body, the potential detriment and risk relates to all types of cancer. Based on these results, the contribution of arsenic to lung cancer risk (95th percentile of 7.14-E-7) is insignificant compared to the risk obtain from radon progeny exposure (95th percentile of 1.3-E-2).

As discussed in Section 4, for Deloro and surrounding area, standardized incidence ratios were high for lung cancer in males compared to Ontario, but not when compared to other geographic areas in Hastings County. There was no evidence of a trend over time (Hasting and Prince Edward Counties Health Unit, 1999).

It is not warranted to combine any of the other parameters of interest in the village based on the independent toxicological properties of all other contaminants.

Discussion of Metals and Radiological Risk Results for Population. The estimated radiological and chemical risks to the 140 adults of Deloro are not large enough to be measurable relative to the background risks. Therefore, there will not be a statistically significant increase in cancer incidence within Deloro over background cancer risks. Theoretically, for Deloro this would translate into 0.0023 additional skin cancer cases per year based on the probabilistic 99^{th} percentile exposure to arsenic over a lifetime and 0.026 additional lung cancer cases per year based on the probabilistic 95^{th} percentile exposure to radon over a lifetime. Because these are fractional cases per year, observing an incident in Deloro is unlikely.

Discussion of Changes in Lifetime Risk Results in the Future. The results provide a lifetime exposure risk estimate for 70 years of exposure. The parameters selected for the assessment are considered to be conservative, and therefore the risk results have been overestimated. Closure of the mine site in the near future will further reduce the risk in the future, albeit slowly, since the source will have been eliminated and concentrations in the village can only decrease.

6. Key Study Findings and Conclusions

The following major study findings are presented and conclusions made based on this study:

1. Sampling indicates that there are elevated levels of arsenic, cobalt, and lead in soils and above-background levels of other contaminants including radon and gamma radiation in some localized areas of the village.
2. The results of the risk study strongly indicate that there are no unsafe exposures or adverse health effects, under the range of conditions considered, associated with the contamination in the village. Although the levels of arsenic and other metals were found to be elevated, the analysis and expert advice supports the conclusion that under the range considered, it is safe to reside in the village and its homes.[1] The most important facts in support of this overall conclusion are:
   - The residents of Deloro do not appear to have, on average, higher levels of arsenic (total and speciated) than the comparison (control) community. Regression analysis showed that the urinary arsenic levels (total and speciated) could not be statistically associated with the characteristics of the population.
   - The levels of arsenic in urine in Deloro are not indicative of any excess levels of morbidity as observed by their self-reports.
   - Characteristics of the places of residence, including the presence of vegetable gardens and use of well water, as well as length of residence in Deloro, were also analyzed using a linear regression. None of the regression coefficients were statistically significant. In addition, the respondents with high levels of arsenic were compared to those with lower levels and none of the variables showed statistically significant association.
   - Overall predicted exposures and risks for arsenic were only slightly greater when compared to estimates for the typical Ontario resident. For example, totalled predicted maximum cancer risk for arsenic in Deloro from all pathways, was less than 0.2 times higher than the maximum risk (99th percentile) for a typical Ontario resident arsenic exposure (1.17 per 1,000 for Deloro versus 0.963 per 1,000 for Ontario). Most importantly, the percent contribution of exposure or dose from soil and dusts (dermal, ingestion and inhalation) was small when compared to arsenic in the normal daily diet. The presence of arsenic in the Ontario diet is due to its natural occurrence as a trace element in the earth and its uptake into crops. There are also various forms of arsenic in food that are considered non-toxic or less toxic than other forms.
   - If all soils in Deloro were replaced with background soils, overall arsenic risk would be reduced by only 2 to 4 percent.

[1] Safe in this context means negligible risk. Safe is arrived at based on comparison to what is typical (i.e. there is no meaningful difference).

- Predicted cancer and non-cancer risk levels for arsenic were only slightly higher for Deloro residents than for individuals living elsewhere in Ontario. For example, it was estimated that roughly 80 percent of lifetime exposure to arsenic in Deloro is from the normal Ontario food basket, as compared to roughly 4% for soil and indoor dust combined. The relative contribution of specific pathways to total lifetime risk (e.g. backyard vegetables, diet, soil). The combined risk from soil, indoor dust, and home-garden produce is one-tenth that of the regular Ontario food basket. Furthermore, the levels of risk for each of the soil and indoor dust and backyard vegetable pathways were found to be in the range that is considered negligible.
- Deloro residents would not experience risks from exposure to lead that were significantly greater than typical Ontario residents would experience. No adverse health effects would be expected to occur at the levels of lead found in the village, as these levels were not unusually high.
- Levels of cobalt and silver in the Village of Deloro are not high enough to result in any measurable health risk. Risks from exposure to nickel in Deloro were comparable to risks for typical Ontario residents.
- The levels of contaminants in drinking water were well below Ontario Drinking Water Objectives for safety.
- The epidemiological review of cancer incidence and mortality data in Deloro and surrounding areas (1980-1995) found that, for the cancers studied, no incidence or mortality rate was high enough to warrant more detailed analysis of the statistics.
- Radiological exposures and lifetime cancer risks predicted for Deloro residents are comparable and in the range of exposures and risks from background radio-activity.

3. With respect to gamma radiation, there was one area (the vacant lot adjacent to the main entrance of the former mine site) that exceeded the 1977 Task Force Federal/Provincial guideline, but the levels were deemed not to be an immediate health concern. In the rest of the village there were only three small pockets (covering an area of no more than a few square metres) with slightly elevated gamma radiation levels, all well within safe levels.

   All radionuclides in soil and dusts were within the range that is typical for the rest of Ontario. A few homes were found to have higher than normal levels of radon gas, although none were above guidelines that require immediate remediation or suggest imminent hazard to health.

Conservative Elements of the Study

Predictions of exposure and risk are only estimates, and these estimates do not necessarily reflect any one person's actual exposure of risk. In fact, exposure will vary among people because of their different activities, the amount of time they spend in contact with a substance, and their age (children tend to have higher exposures because of their smaller body weight). As a precaution, various assumptions are made in these studies that tend to overestimate risk to a considerable degree.

These conservative assumptions include, for example:

- Use of the USEPA toxicity factors and cancer slopes for calculating risk. These factors are considered by USEPA as overestimating the risks. The expert peer review agreed that the risk values would be overestimated. There are large uncertainty or safety factors placed in these toxicity factors.

- In many cases, environmental concentrations were not detectable. However, rather than assume they are not there, the study assumes that they are present at half the detection limit and bases the risk calculations on this. Using a more sensitive method of analysis would likely demonstrate lower risks than were calculated.

- Although household swipe samples detected very little contamination in dust, the study team recognized that this was not an indication that contaminants were not present in homes, but rather they were not present in the dusts that persons would have the most direct contact with. Vacuum samples were not collected because these methods tend to underestimate risk. Instead the study assumed that indoor dust was contaminated in relation to the levels outside the house, and risk estimates were based on that assumption.

- Backyard gardens sampled did not have the highest levels of arsenic in soil. Therefore the risk assessment modelled what levels in fruits and vegetables might be in other areas of the village. In other words, theoretical garden conditions were modelled that were not evident in the village.

- Risk estimates are based on a lifetime of exposure over 70 years. In most cases persons do not live in one area over their whole lifetime. As such, for many people, this is another factor that overestimates the risk calculations.

In the study chemical concentrations were assumed to remain unchanged in the future. This assumption overestimates risk, since with the closure of the mine site metals in the village will decrease over time, albeit slowly.

Overall Conclusions

1. Sampling indicates that there are elevated levels of arsenic, cobalt, and lead in soils and above-background levels of other contaminants including radon and gamma radiation in some localized areas of the village.

2. However, the results of the risk study strongly indicate that there are no unsafe exposures or adverse health effects associated with the contamination in the village. Although the levels of arsenic and other metals were found to be elevated due to the past century of industrial activity at the mine, the analysis and expert advice supports the conclusion that it is safe to reside in the village and its homes.[2]

[2] Safe in this context means negligible risk. Safe is arrived at based on comparison to what is typical (i.e. there is no meaningful difference).

7. References

Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service, 1992. Draft Toxicological Profile for Nickel, p.152. (Cited In: Health Canada, 1994)

Alexander, F.W., 1974. The Uptake of Lead by Children in Differing Environments. *Environ Health Perspet* 7:155-159

American Conference of Governmental Industrial Hygienists (ACGIH), 1991. Documentation of the Threshold Limit Values and Biological Exposure Indices. Sixth Edition. Cincinnati. ISBN 0-936712-96-1

Blake, K.C.H., 1976. Absorption of 203Pb from Gastrointestinal Tract of Man. *Environ Res* 11:1-4

Brain, D.B., and Moiser, M.J., 1980. Deposition and Clearance of Grain Dusts in the Human Lung. In: Dossman, J.A., and Cotton, D.J. (Eds.). Occupational Pulmonary Disease: Focus on Grain Dust and Health. pp. 77-94

Brown, C.C., and Chu, K.C., 1983. Implications of the Multistage Theory of Carcinogenesis Applied to Occupational Arsenic Exposure. JNCI 70:455-463

Bucher, J.R., Elwell, M.R., Thompson, M.C., Chou, B.J., Renne, R., and Ragan, H.A., 1990. Inhalation Toxicity Studies of Cobalt Sulfate in F344/N Rats and B6C3F1 Mice. *Fund Appl Toxicol* 15(2): 357-372

CANTOX Environmental, December 1999. Deloro Village Exposure Assessment and Health Rrisk Characterization for Arsenic and Other Metals

CH2M Gore & Storrie Limited., December 1999. Deloro Village Environmental Health Risk Study – Summary Report of Air, Settled Dust, and Drinking Water Sampling and Analysis Activities

Chamberlain, A.C., Heard, M.J., Little, P., Newton, D., Wells, A.C., and Wiffen, R.D., 1978. Investigations into Lead from Motor Vehicles. United Kingdom Atomic Energy Authority, Harwell, United Kingdom. Report No. AERE-R9198

Deloro Health Risk Study Technical Steering Committee, June 1998. Draft: Terms of Reference – Deloro Village Environmental Health Risk Study

Dunnick, J.K., Elwell, M.R., Benson, J.M., Hobbs, C.H., Hahn, F.F., Haly, P.J., Cheng, Y.S., and Eidson, A.F., 1989. Lung Toxicity after 13-week Inhalation Exposure to Nickel Oxide, Nickel Subsulfide, or Nickel Sulfate Hexahydrate in F344/N Rats and B6C3F1 Mice. *Fund Appl Toxicol* 12(3): 584-594

Enterline, P.E., and Marsh, G.M., 1982. Cancer Among Workers Exposed to Arsenic and Other Substances in a Copper Smelter. *Am J Epidemiol* 116(6): 895-911

Environment Canada, 1993. Arsenic and Its Compounds. Environment Canada/Health and Welfare Canada (Canadian Environmental Protection Act: Priority Substances List Assessment Report) No.14

Freeman, G.B., Schoof, R.A., Ruby, M.V., Davis, A.O., Dill, J.A., Liao, S.C., Lapin, C.A., and Bergstrom, P.D., 1995. Bioavailability of Arsenic in Soil and House Dust Impacted by Smelter Activities Following Oral Administration in Cynomolgus Monkeys. *Fund Appl Toxicol* 28(2): 215-222

Furchner, J.E., Richmond, C.R., and Drake, G.A., 1968. Comparative Metabolism of Radionuclides in Mammals – IV. Retention of Silver – 100 m in the Mouse, Rat, Monkey and Dog. *Health Phys* 15:505-514

Gaul, L.E., and Staud, A.H., 1935. Clinical Spectroscopy: Seventy Cases of Generalized Argyrosis Following Organic and Colloidal Silver Medication, Including a Biospectrometric Analysis of Ten Cases. JAMA 104:1387-1390

Goss Gilroy Inc., December 1999. Deloro Village Environmental Health Risk Study, Final Report

Harp, M.J., and Scoular, F.I., 1952. Cobalt Metabolism of Young College Women on Self-Selected Diets. J Nutr 47:67-72. (Cited In: ATSDR, 1997)

Hastings and Prince Edward Counties Health Unit, December 1999. Summary Report on the Review of Cancer Incidence and Mortality Data in Hastings and Prince Edward Counties and Eastern Ontario: A Focus on Deloro and Surrounding Area, 1980-1995

Hastings and Prince Edward Counties Health Unit, December 1999. Summary Report on the Cancer Incidence and Mortality Data in Hastings and Prince Edward Counties and Eastern Ontario, 1980-1995.

Health Canada (1998). The Health and Environment Handbook for Health Professionals

Higgins, I., Welch, K., and Burchfiel, C., 1982. Mortality of Anaconda Smelter Workers in Relation to Arsenic and Other Exposures. Department of Epidemiology, University of Michigan. Ann Arbor, MI. (Cited In: U.S. EPA, 1984b)

Holland, R.H., McCall, M.S., and Lanz, H.C., 1959. A Study of Inhaled Arsenic-74 in Man. *Cancer Res* 19:1154-1156

Hopenhayn-Rich, C., Smith, A.H., and Goeden, H.M. 1993. Human Studies Do Not Support the Methylation Threshold Hypothesis for the Toxicity of Inorganic Arsenic. *Environ Res* 60(2):161-177

International Commission on Radiological Protection (ICRP), 1991. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60, Ann. ICRP: 21(1-3)

International Commission on Radiological Protection (ICRP), 1996. Age-Dependent Doses to Members of the Public from Intake of Radionuclides: Part 5 Compilation of Ingestion and Inhalation Dose Coefficients. ICRP Publication 72, Ann. ICRP 26(1)

J.L. Richards & Associates Limited, January 1998. An Historical Analysis of the Deloro Site

Karhausen, L., 1973. Intestinal Lead Absorption. In: International Symposium, Environmental Health Aspects of Lead. Commission of European Communities, C1D, Luxembourg, pp.427-440. (Cited In: HWC, 1980)

Kehoe, R.A., 1961. The Metabolism of Lead in Man in Health and Disease. In: The Harben Lectures (1960). *J R Inst Public Health Hyg* 24:1

Lee-Feldstein, A., 1983. Arsenic and Respiratory Cancer in Man: Follow-up of an Occupational Study. In: Lederer, W., and Fensterheim, R. (Eds) Arsenic: Industrial, Biomedical and environmental perspectives. Van Nostrand Reinhold, New York. (Cited In: U.S. EPA, 1984a)

Ministry of Labour, 1996. Occupational Health and Safety Act.

MOE Ontario Ministry of the Environment, 1994b. Assessment of the Toxicology, Human Exposure and Health Risks of Inorganic Arsenic. Standards Development Branch. December 1994

MOE, 1997. Guideline for Use at Contaminated Sites in Ontario. June 1996, as updated February 1997. Ontario Ministry of Environment and Energy

MOE, February 1998. Screening Level Assessment of Exposure and Associated Risk to Arsenic in Deloro Village, Ontario

MOE, March 1998. Phytotoxicology Investigations Conducted in the Vicinity of the Former Deloro Smelter, Deloro, Ontario, 1986-1987

MOE, July 1999. The Deloro Village Environmental Health Risk Study Summary Report, PIBS 794E

MOE, December 1999. Phytotoxicology Technical Memorandum. Phytotoxicology 1998 Investigation: The Village of Deloro, Ontario. Standards Development Branch, Report No. SDB-056-3511-1998

MOEE (Ministry of the Environment and Energy), 1994a. Assessment of the Toxicology, Human Exposure, and Health Risks of Inorganic Arsenic. Standards Development Branch. December. Appendices 2 through 5. (Cited In: Gradient Corporation, 1995). Exposure assessment Place Dome Balmertown, Ontario, Canada

MOEE Ontario Ministry of Environment and Energy, 1994a. Soil, Drinking Water, and Air Quality Criteria for Lead: Recommendations to the Minister of the Environment and Energy. ACES (Advisory Committee on Environmental Standards) Report No. 94-02

MOEE Ontario Ministry of Environment and Energy, 1994c. Ontario Drinking Water Objectives

MOEE, 1993. Ontario Typical Range of Chemical Parameters in Soil, Vegetation, Moss Bags and Snow. Version 1.0a. PIBS 2792

Moore, M.R., Meredith, P.A., Watson, W.S., Sumner, D.J., Taylor, M.K., and Goldberg, A., 1980. The Percutaneous Absorption of Lead-203 in Humans from Cosmetic Preparations Containing Lead Acetate, as Assessed by Whole-Body Counting and Other Techniques. *Food Cosmet Toxicol* 18:399-405

Mushak, P., 1991. Gastro-Intestinal Absorption of Lead in Children and Adults: Overview of Biological and Biophysico-Chemical Aspects. *Chem Speciation Bioavail* 3(3/4): 87-104

Nielsen, G.D., Anderson, O., and Jensen, M., 1993. Toxicokinetics of Nickel in Mice Studied with the G-emitting Isotope 57Ni. *Fund Appl Toxicol* 21-236-243

NTP, 1991. Toxicity Studies of Cobalt Sulfate Heptahydrage in F344/N Rats and B6C3F1 Mice (inhalation studies). National Toxicology Program. Research Triangle Park, NC

OCWA, February 1997. Monitoring Data Summary Volumes I & II, Deloro Mine Site

Ontario Ministry of Labour, Radiation Protection Service, 1986. Deloro Arsenic Treatment Plant & Deloro Satellite Property Gold Mine

Pomroy, C., Charbonneau, S.M., McCullough, R.S., and Tam, G.K.H., 1980. Human Retention Studies with 74As. *Toxicol Appl Pharmacol* 53(3): 550-556

Richardson, M.G., 1997. Compendium of Canadian Human Exposure Factors for Risk Assessment. O'Conner Associates

SENES Consultants Limited, December 1999. The Results of Environmental Radiation Monitoring Conducted in Support of the Deloro Village Environmental Health Risk Assessment

SENES Consultants Limited, December 1999. Radiological Health Risk Assessment for the Village of Deloro

Smith, M.K., George, E.L., Stober, J.A., Feng, H.A., and Kimmel, G.L., 1993a. Perinatal Toxicity Associated with Nickel Chloride Exposure. *Environ Res* 61:200-211. (Cited In: Health Canada, 1994)

Sorbie, J., Olatunbosun, D., Corbett, W.E.N. et al., 1971. Cobalt Excretion Test for the Assessment of Body Iron Stores. *Can Med Assoc J* 104:777-782. (Cited In: ATSDR, 1997)

Thompson, J.A., 1971. Balance Between Intake and Output of Lead in Normal Individuals. *Brit J Ind Med* 28:189-194

Tseng, W.P., 1977. Effects and Dose-Response Relationships of Skin Cancer and Blackfoot Disease with Arsenic. *Environ Health Perspect* 19:109-119

Tseng, W.P., Chu, H.M., How, S.W., Fong, J.M., Lin, D.S., and Yeh, S., 1968. Prevalence of Skin Cancer in an Endemic Area of Chronic Arsenicism in Taiwan. *J Nat Cancer Inst* 40(3):453-463

U.S. EPA. 1999. Health Effects Assessment Summary Tables (HEAST)

U.S. EPA., 1986. Health Assessment Document for Nickel and Nickel Compounds (Final Report). NTIS PB-86-232212

US EPA, 1998. Integrated Risk Information System (IRIS)

Valberg, L.S., Ludwig, J., and Olantunkosun, D., 1969 Alterations in Cobalt Absorption in Patients with Disorders of Iron Metabolism. *Gastroenterology* 56:241-251. (Cited In: ATSDR, 1997)

Wahlberg, J.E., 1965. Percutaneous Toxicity of Metal Compounds. *Arch Environ Health* 11:201-204

Wester, R.C. Maibach, H.I., Sedik, L., Meledres, J., and Wade, M., 1993. In Vivo and In Vitro Percutaneous Absorbtions and Skin Decontamination of Arsenic from Water and Soil. *Fund Appl Toxicol* 20, 236. (Cited In: Hrudey, et al., 1996)

Ziegler, E.E., Edwards, B.B., Jensen, R.L., Mahaffey, D.R., and Foman, S.J., 1978. Absorption and Retention of Lead by Infants. *Pediatr Res* 12:29-34. (Cited In: Mushak, 1991)

APPENDIX A

TECHNICAL STEERING COMMITTEE, CONSULTANTS, AND PEER REVIEWERS

Technical Steering Committee

Murray Dixon is a Toxicity Assessment Scientist with the Ministry of the Environment. He holds his Honours B.Sc. and his M.Sc in Botany, both from the University of Toronto. He has been with the Ministry of the Environment for 13 years. He has studied a wide range of contaminants during his tenure at MOE, including in-depth experiments into the effects of arsenic on plants.

Scott W. Fleming is Senior Toxicologist within the Standards Development Branch of the Ontario Ministry of the Environment. He obtained his graduate degree from the University of Toronto in 1985, where his research studies were in the field of neurotoxicology. Mr. Fleming is a recognized Canadian expert in the fields of toxicology and human health risk assessment of environmental contaminants. He has conducted a number of large-scale community health risk studies within the province of Ontario and co-author of the Ministry's Guidance on Site Specific Risk Assessment for Contaminated Sites. His award-winning work on development of environmental standards for lead formed the scientific basis for the tough new standards on this substance in Ontario. In addition, he has developed environmental and occupational exposure limits for a variety of toxic substances and has published numerous scientific reports and learned articles.

Mr. Glen Hudgin is currently Director of Public Health Inspection for the Hastings and Prince Edward Counties Health Unit. He was born in Picton, Ontario. He is a Canada Certified Public Health Inspector. He earned his Bachelor's Degree in Environmental Health from Ryerson Polytechnical University. He was first employed as a Student Public Health Inspector in the Picton Office of the Hastings and Prince Edward Counties Health Unit. He carried out one of the first bacteriological water quality studies of the Bay of Quinte in 1970. Previously, Mr. Hudgin was employed as a District Public Health Inspector for the city of North York Health Department. When there, he carried out a bacteriological study of the North York segments of the Don River, Humber River and Black Creek.

Dr. Michael A. McGuigan, MD, MBA is an Associate Professor of Pediatrics, Pharmacology, and Health Administration in the Faculty of Medicine at the University of Toronto. A graduate of McGill University medical school, he finished his post-graduate training in clinical pharmacology and toxicology at Harvard University's Children's Hospital in Boston and was certified as a medical toxicologist by the American Board of Medical Toxicology. In 1980, Dr. McGuigan assumed the position of Medical Director of the Ontario Regional Poison Information Centre at The Hospital for Sick Children in Toronto. He is

past-President of the American Academy of Clinical Toxicology and current President of the Canadian Association of Poison Control Centres.

Dr. Lynn Noseworthy has been a Medical Officer of Health since 1991 at the Hastings and Prince Edward Counties Health Unit. She completed her Doctor of Medicine Degree in 1979 at Memorial University of Newfoundland. In 1987, Noseworthy went on to complete her Master of Health Science Degree in Community Health and Epidemiology at the University of Toronto.

Jim Ritter is the Ontario Ministry of the Environment's Project Manager and Operations Engineer for the Deloro Mine Site Rehabilitation Project. He started his career working for the Federal Department of National Defence and has also held positions with the Ministry of Labour, the Industrial Health & Safety Branch and private industry. A Civil Engineer and a Canadian Registered Safety Professional, Mr. Ritter has been working on mine rehabilitation efforts in Deloro since 1992.

Arthur Scott is an expert in radon and radioactivity who currently works with the Ontario Ministry of Labour's Radiation Protection Service. Prior to joining the Ministry, Mr. Scott directed field research on radon for the U.S. Environmental Protection Agency and oversaw radiation cleanup programs in Elliot Lake, Ontario and Uranium City, Saskatechewan for Canada's Atomic Energy Control Board. He earned his M.A. in Physics and M.Sc. in Radiation Biology and Radiation Physics at the University of London.

Dr. Lesbia F. Smith, M.D. is a senior medical consultant with the Ontario Ministry of Health's public health branch and an assistant professor at the University of Toronto's Department of Public Health Sciences. She specializes in environmental health and toxicology.

Adam C. Socha is Senior Advisor, Toxicology at the Standards Development Branch for the Ontario Ministry of the Environment. He has served as a toxicologist and technical manager with the MOE for over 12 years, specializing in human toxicology and the environmental behaviour of contaminants. Mr. Socha received his B.Sc. degree in pharmacology from the University of Toronto in 1983 and his M.Sc. degree in toxicology and physiology from the Ontario Veterinary College, University of Guelph in 1986. He is a member of the Society of Environmental Toxicology & Chemistry and the Society of Toxicology of Canada.

Consulting and Analytical Expertise

CH2M Gore & Storrie Limited is an employee-owned, Canadian-controlled corporation formed in 1995 through the merger of CH2M HILL Engineering Ltd. and Gore & Storrie Limited, both recognized leaders in the field of environmental engineering. With the combined resources of more than 300 employees Canada-wide, CG&S offers a complete range of environmental services and technologies to our clients across Canada and in the global market. The CG&S team of engineers, planners, hydrogeologists, scientists, and technical specialists is committed to providing environmental consulting services in all aspects of water, wastewater, and waste management for public and private sector clients. Our dedication to safeguarding the environment and being responsive to the increasingly specialized needs of our clients remains the cornerstone of our success.

Goss Gilroy Inc. (GGI) is a privately-owned Canadian company established in 1981 to provide quality management consulting services to private and public sector organizations. We provide our clients with services and technical expertise in the areas of surveys and statistical consulting, project and program evaluation, market research, information technology, and comprehensive and internal audits. The technical strength of our firm's professional staff is augmented by operational and management experience gained from working closely with industry and government. Our projects cover subject areas including health, environment, natural resource management, industry, agriculture, technology transfer, research and development, employment, and regional economic development.

Cantox Environmental Inc. is a science-based consulting firm specializing in providing expert advice to clients on toxicology issues related to human health, the environment and regulatory affairs. Our scientific staff, in five offices across Canada and the United States, includes more than 50 professionals with experience that encompasses diverse areas of human and aquatic toxicology, environmental fate and modelling, human health and environmental risk assessment, and risk communication. We have been providing a full range of consulting services to industry, government, trade associations, scientific organizations, financial institutions, and the legal profession for more than 15 years.

SENES Consultants Limited is a wholly-owned Canadian company that provides specialty services on a broad spectrum of projects that typically involve provision of expert advice on specific environmental issues; preparation of environmental and ecological risk assessments; site investigations; environmental audits; low-level radioactive and hazardous waste investigations

and design of applicable management systems; assessment and cost–benefit analysis of environmental control technologies; preparation of facility audits and development of environmental quality management systems; aquatic ecosystem assessment and management; atmospheric chemistry, monitoring, and dispersion modelling; and various aspects of mining including environmental impact assessments, development of decommissioning plans, and assessment of acid mine drainage. We provide services to regulatory agencies from all levels of government as well as to private sector companies, industrial associations, and public organizations.

External Peer Reviewers

Dr. Charles Abernathy is a toxicologist for the U.S Environmental Protection Agency's Office of Water. He has carried out extensive scientific research on behalf of the Veterans Administration Medical Center in Washington D.C. for more than 10 years. The author of more than 70 scientific articles in professional journals, Dr. Abernathy holds a M.Sc. from the University of Kentucky and a Ph.D. from North Carolina State University. He also received postdoctoral training in pesticide toxicology at the University of California, Berkeley.

Dr. Henry S. Caplan is the Head of Physics and Engineering Physics at the University of Saskatchewan. In addition to being published in more than 100 academic journals and abstracts, Dr. Caplan is recognized as an expert in the analysis of radiation hazards and mitigating procedures for mine workers and the environment. He received his B.Sc. in Experimental Physics and a Ph.D. in Nuclear Physics from the University of Glasgow.

Dr. Willard Chappell is a Physics Professor at the University of Colorado. The founder and Director of the Center for Environmental Sciences at the University of Colorado between 1979 and 1989, he is the co-chair and principal organizer for the Society of Environmental Geochemistry International Conferences on Arsenic Exposure and Health Effects. Dr. Chappell holds a Ph.D in Physics from the University of Colorado.

Mark J. Gardiner is the Technical Supervisor of the Port Hope Field Services Office (PHFSO) of the Low-Level Radioactive Waste Management Office (LLRWMO). In this capacity he oversees environmental monitoring, site characterization and project planning services for PHFSO activities within the mandate of the LLRWMO in Canada. Mr. Gardiner has been with the LLRWMO for over 10 years, specializing in environmental monitoring program development, environmental investigation/remediation planning and facility licensing. He is currently acting as a technical advisor to Natural Resources Canada in the development of a long-term management plan for historic

low-level radioactive wastes in the Port Hope area. Mr. Gardiner received his B.Sc. in Physical Chemistry from Trent University.

Raymond E. "Buck"Grissom, Jr., Ph.D. is a senior toxicologist at the Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, in Atlanta, Georgia. He provides primary peer review and analysis of health consultations written by staff at the ATSDR. He is responsible for providing expert toxicological and technical advice and appropriate recommendations about potential health impacts resulting from emergency and non-emergency situations involving the release or potential release of hazardous substances. He prepares written health consultations for ATSDR headquarters, regional field personnel, and other government agencies (federal, state, and local). He represents ATSDR at conferences, public meetings, and meetings with representatives of other federal agencies, state and local agencies. His other responsibilities include writing manuscripts for publication, and reviewing, evaluating, and critiquing the work of other environmental and health science professionals.

Dr. Grissom is a graduate of North Carolina State University at Raleigh, North Carolina. He is a member of the American Association for the Advancement of Science, Sigma Xi, Society of Toxicology, the Southeast Chapter of Society of Toxicology, and the Gamma Sigma Delta Honor Society.

Dr. Chris Le is an Associate Professor with the University of Alberta's Department of Public Health Sciences whose expertise includes ultrasensitive assays for DNA damage and environmental contaminants; chemical speciation of trace elements; the exposure and health effects of arsenic; and biomarkers.

Dave McLaughlin is an adjunct professor at the University of Toronto's Faculty of Forestry and an Investigations Co-ordinator with the Ontario Ministry of the Environment's Phytotoxicology and Soil Standards Section. He has 21 years experience in environmental investigations and has published numerous reports and scientific papers on environmental contaminants in soil and the effects of pollution on plants and forest ecosystems. Mr. McLaughlin earned his B.Sc. and M.Sc. in Forestry from the University of Toronto.

Dr. Bliss Tracy has been a research scientist with Health Canada since 1978. He received his B.Sc. from the University of New Brunswick and his Ph.D. in nuclear physics from McMaster University. Mr. Tracy's recent work includes projects related to radionuclide monitoring for the Comprehensive Test Ban Treaty and to preparations under the Federal Government's Nuclear Emergency Plan.

Appendix B

Draft Terms of Reference

DRAFT

Terms of Reference

Deloro Village Environmental Health Risk Study

June 1998
Deloro Health Risk Study Technical Steering Committee

Ontario Ministry of the Environment
in consultation with
Hastings -Prince Edward County Health Unit and

The Ontario Ministry of Health

I. Study Objectives and Overview

Previous MOE soil surveys of the Village of Deloro have indicated that soil is significantly contaminated with arsenic and cobalt (i.e. exceeds provincial clean-up guidelines) and marginally contaminated with lead, nickel and silver (above Ontario background levels). In addition there have been historical concerns regarding the processing and disposal of radioactive materials, and the presence of radon gas in this community. Based on a screening level risk assessment conducted by MOE (Fleming and Kuja, 1998), it was concluded that there was sufficient evidence to warrant a more comprehensive evaluation of exposure and potential risk to residents. There are approximately 65 residences in Deloro and a population of 140 with 40 children age 6 and under.

The study will combine sampling survey data which has been and continues to be collected by Ministry experts together with additional sampling requirements to be carried out by the specified consultant firms. The Ministry has made a public commitment to utilize the very best available technical expertise and as such a group of consulting firms with high level knowledge and experience in specific technical areas are identified. These will work under the co-ordination of CH2MI Gore and Storrie (CG&S), the Ministry's consultant for the on-site contamination assessment and rehabilitation.

The specific objectives of the study which must be achieved by this team of expertise are the following:

1 To determine if there are elevated levels of contaminants

from the former Deloro mine site present in the community in various environmental media (soils, indoor and outdoor dusts, indoor and outdoor air, drinking water, backyard vegetables). This will involve a comprehensive sampling and analysis for arsenic as well as other metals (cobalt, uranium, lead, nickel and silver), radionuclides (U238, Ra226), gamma radiation, and radon gas in homes.

2. To quantify the potential exposure of community residents through : (I) deterministic and, as specified, probabilistic exposure modelling and (ii) biological monitoring of urinary arsenic in community residents together with risk factor questionnaire administration and analysis.

3. To quantify the potential exposure from contaminated soils/dusts relative to other potential sources of exposure.

4. To quantify to what degree, if any, there may be increased health risks in the Deloro community and characterize the possible significance of such risks based on the exposure modelling and biological monitoring results.

5. To utilize the US EPA model for prediction of urinary arsenic levels to compare predicted versus observed values in the community.

6. To conduct a thorough information collection and provide a technical summary of applicable risk mitigation efforts and outcomes in other jurisdictions involving contamination of residential communities of arsenic associated with mine tailing or smelter operations.

As a component of the study design process, a focus

questionnaire was developed and administered to seven volunteer households in Deloro Village in May of this year. In short, the survey indicated that there is no notable swimming activity in, or fish consumption from the Moira River in the area of the mine site or Village. Two of seven families indicated groundwater use for drinking and bathing. Generally, village air was characterized as very dusty. It was also indicated that some children do play directly on the mine site. These factors were considered in the design of the study and as such emphasis has been placed on soil, dusts and drinking water and there has been elimination of fish consumption and recreational swimming as pathways for data collection and exposure modelling.

II. Description of Major Components

I. Overall Project Management and Coordination (CG&S)

Key task include:

- development of an overall logistical plan based on discussion with individual firms responsible for various components of the study.
- subcontracting of components to firms specified below
- co-ordination of required technical meetings, updates, report preparation.
- ensuring co-ordination of solicitation of participation by community residents in study.
- provision of progress reports at quarterly phases of the study.
- identification and negotiation of technical differences.
- ensure technical consistency and quality across various components of the study.
- preparation of an overall technical summary of the study

and findings.
- preparation of a plain language summary of the findings and public presentation materials (overheads. Fact sheets, etc).
- ensuring efficiency and coordination in environmental sampling such that there is minimal inconvenience or intrusion for residents.
- securing costing estimates for each component and for the overall study.

ii. Environmental Sampling, Analysis and Reporting for Metals © G&S)

Key task include:

soil

No further soil collection is required. This spring the Ministry took over 300 soil samples from residences, gardens, and public areas. Duplicate soil samples were collected from all front and all back yards in Deloro. In each duplicate sample there were at least 16 cores collected in an X or Z pattern across the area of interest. Several of the houses were semi detached, but staff sampled the front and back yards of both sides of the semi. In addition, we took depth samples 0-5, 5-10 and 10-15 cm, from 8 properties selected to represent the north middle and south areas of Deloro. Selection of backyards for depth sampling was based on observation that were open and uncluttered and not obviously disturbed (eg. properties were avoided where pools had been put in or where the neighbour indicated a foundation had been recently excavated , etc). In addition, MOE took duplicate surface samples from a play ground that was being cleaned

up just off the lane to the west of O'Brien Street. Also, MOE staff sampled along two lines, about 200 m west and south of Deloro, in an attempt to get soil with low arsenic levels so we could close off the Surfer As contours.

It is projected that the lab analysis of this data will be completed in July 1998. Subsequently Ministry staff will prepare a technical report of this work which will form one component of this study's documentation.

Indoor air and dust

Sampling and analytical methods for air must cover the range of air concentrations associated with negligible risk as considered by the Ministry (the recommended revised 24 hour air quality criteria for arsenic is 50ng/m^3.Indoor air and dust samples will be collected from all households wishing to participate. Also public buildings (library, community centre). Three methods will be employed:

1. For suspended particles, fixed lo-vol sampler in two locations the main entrance and one other. For households with children this will be the most common indoor play area e.g a child's bedroom.(see Que Hee et al. , 1985). Two 24 hour samples taken at separate periods.

2. For measurement of recently settled dust and rate of deposition, one passive polyethylene bucket placed in home to measure settled house dust (8 week deployment).

3. for determination of integrated concentrations of interior dust two or three 100cm2 swipes of interior surface to measure surface dust in areas where dust is expected to accumulate (e.g counter tops).

Outdoor dusts

Six swipe samples of road dust (paved or gravel surface) are to be collected from across the village area and analysed.

Six swipe samples of dust from other exterior surfaces where dusts are likely to settle and be available for direct exposure. (.e. not roofs)

Outdoor air

Suspended particulate matter in outdoor air will be measured via fixed samplers in a total of six outdoor locations across the village in a manner which is close to residences and sufficiently representative of the air quality and potential variability across the area for the purposes of human exposure modelling.

Drinking Water.

Several Deloro residences utilize ground water wells and are not on the municipal distribution system. For these homes, first draw samples at the tap should be collected in the morning. Flushed (five minute) and unflushed samples will be collected and analysed. Available water supply analytical results can be used for estimating exposures to those on the system.

Backyard Garden Vegetables

A garden study has been initiated by the MOE and seedlings have been planted in the gardens of volunteers. Lettuce, green bean, beet and carrot (vegetable t type selected based on As sensitivity (bean), root crops likely to be consumed by both adults and children (beet and carrot) and a leafy vegetable to examine uptake and dust deposition (lettuce). Samples will be collected by Ministry phytotoxicology staff in August. Approximately 60 samples will be taken in total from six separate gardens.

iii. Environmental Sampling and Analysis for Radioactivity (Low Level Radioactive Waste Management Office -Port Hope)

Key tasks include:

Radionuclide analysis of soil samples from Ministry spring survey is currently in progress (no further sampling required).

Gamma radiation survey of the entire village area at medium density will be carried out.

Radon measurements in air in each participating home will be taken utilizing the E-PERM device atr a four week deployment.

Report preparation.

iv. Biological Monitoring, Risk Factor Questionnaires and Analysis (Goss, Gilroy and Associates)

Key tasks include:

Sampling and measurement of total and speciated urinary arsenic levels in children and adults of the Deloro community (all who wish to participate). Creatinine will also be measured. First morning voided urine samples will be collected. Determination of the distribution of urinary arsenic levels in these individuals. Other tasks include:

- use of an appropriate sample quality assurance/quality control protocol.
- identification of and sampling and measurement of speciated urinary arsenic in a suitable reference population.
- design and administration of a risk factor interview questionnaire for arsenic exposure (modelled on the blood lead studies questionnaires with a few modifications). This questionnaire will also solicit information on health status and morbidity.
- if individuals are observed who exhibit elevated urinary arsenic and if sample size is large enough to provide for sufficient statistical power (e.g. 80% chance of detecting a 9-14% difference in average arsenic levels in two subpopulations) undertake a quantitative analysis of risk factors, testing specific hypotheses of association between urinary arsenic and levels in environmental media.
- report preparation

v. Exposure Assessment and Health Risk Characterization for Arsenic and other metals (CANTOX, human health division)

The keys tasks include:

- conducting and documenting a summary review of the relevant literature studies regarding exposure to arsenic and other metals in the vicinity of mining operations/smelter.

Concurrently, information regarding the various risk management measures applied in these other situations will be collected.

- utilizing the environmental data collected, as well as literature information on arsenic levels in diet, conduct a multimedia exposure assessment providing quantitative deterministic estimates for the following groups:
    - adult and children exposure groups
    - municipal supply versus ground water well users
    - backyard vegetable consumers versus non consumers.

Estimates of the average or typical exposure as well as the maximally plausible exposure shall be provided. Comparison of exposure and associated risk to other Ontario populations will be carried out by the consultant.

Exposure pathways for analysis are :

- ingestion of drinking water
- ingestion of soil/dust
- ingestion via backyard vegetable consumption
- ingestion via general food basket
- inhalation of particulate
- showering (inhalation of aerosol)
- dermal contact

-for arsenic exposure, probabilistic methods will be applied and probability distribution functions for lung and skin cancer risk and non-cancer effects will be developed. This form of analysis will also be applied for other metals where exposures as determined by the deterministic level analysis are considered significant from a health perspective.

-Exposure calculations will be carefully compared against the most current literature and unit risk values. The possible significance of these calculated risks, if any , will be discussed at length. The assessment will also consider the results of the biomonitoring component of the study and provide a cohesive, connected analysis of the two data sets.

-Uncertainty and sensitivity analysis will also be conducted and appropriately interpreted.

-Various options for exposure/risk mitigation based on review of experience in other jurisdictions will be presented together with estimates of possible risk reduction
-this portion of the study will also include runs of the US EPA model for urinary arsenic and comparison to the observed results.
-report preparation

vi. Exposure Assessment and Health Risk Characterization for radionuclides, gamma radiation and radon (SENES Consultants).

The major tasks include:

-based on the data collected calculations of total exposure via various pathways will be carried out for adults and children.
-Incremental lifetime risk estimates will be provided utilizing deterministic and probabilistic methods.
-comparison of exposure and risk to other areas of the province.
- health significance of the findings, if any, will be thoughtfully discussed in view of the most recent literature regarding health effects of radioactivity.
-report preparation.

VII. Summary report (CG&S)

- overview of findings
- address questions of interactions and risk additivity
- provide risk management options, if any required.

III . Documentation To be Produced

1. Report on 1998 soil survey and backyard garden vegetable sampling and results to be prepared by MOE {Murray - estimated dates??)
2. Report on 1998 air , dust and drinking water sampling and results -(CG&S)
3. Report on 1998 gamma radiation and radon surveys.(LLRWMO)
4. Report on Urinary Arsenic Levels and Risk Factors (Goss Gilroy Associates)
5. Report on Exposure Assessment and Risk Characterization for as and other metals in Deloro Village (Cantox Inc)
6. Report on Exposure Assessment and Risk Characterization for Radioactivity in Deloro Village (SENES consultants)
7. Summary Overview Report (CG&S)
8. Plain Language report (CG&S)

IV. Reporting Relationships

The co-ordinating firm shall ensure clear communications between all parties involved in the study. Individual firms will discuss all significant technical issues with the chair of the MOE Technical Steering Committee (S. Fleming, Standards Development Branch) directly and concurrently with the co-ordinating firm representative. In particular, scope, schedule and cost changes. Individual firms will

be responsible for the technical integrity of their component of the study. The co-ordinating firm will be responsible for logistics and process integrity.

All reports will be produced for the Ministry of the Environment. All data and information related to the study are the property of the Ministry of the Environment and will be released through the Ministry of Environment. No reference will be made to specific individual community residents or property addresses in any of the draft or final reports. No data or analysis or part thereof will be published in any journal or scientific literature without the expressed permission of the MOE and participation of the MOE technical steering committee. In addition, all media inquiries must be referred to a designated MOE contact and no firm or its representatives shall grant media interviews regarding the study.

V. Major Milestones and Timing Requirements

July 1998 - MOE soil survey lab results returned
July 22 1998 - Logistical Plan, schedule and cost estimates provided to MOE
July 31, 1998 - MOE reviews and approves plan and cost, CG&S execute subcontracts
August 12, 1998 - Meeting of all consultants for initiation/clarifications
End August 1998 - all environmental and urine sampling to be completed (exception of passive dust monitor which requires 8 week deployment)
Early September 1998 - update meeting of all parties
Early October - all laboratory analysis complete, biological monitoring report draft,

Nov 15 - first draft of all supporting technical reports -re sampling and analysis
Dec 15 First Draft - risk assessment reports and summary report provided to technical steering committee and external expert (to be determined)
Jan 10/99 - review comments returned
Jan 31 - final reports submitted
Note: all firms may be required to participate in one public meeting and one meeting with the Technical Steering Committee where findings are presented. Other meetings may be required with individuals at extra cost.

VI Other Considerations

MOE is also undertaking a site-specific risk assessment (SSRA) with respect to the on-site contamination issue at the Deloro mine site, It is important that technical consistency be maintained between the offsite community health risk assessment and the on-site SSRA. At the same, there will be some differences in method and interpretative approach because of the differing objectives of an assessment carried out for decommissioning purposes versus one carried out for evaluating ongoing potential health risk in an existing community. Consistency between the radioactivity and metals exposures assessment must also be maximized.

Because of the MOE public commitment to high excellence in conduct of this important study, it is expected that reports will be written (particularly risk analysis and interpretation) in large part directly by senior expert staff in the contracted consulting firms (not an overview function of junior staff).

Duplication of effort in documentation must be avoided and should be structured/interfaced to feed easily into a common format for the

overview report. All reports will be produced using Corel WP8 for Windows and will be provided in both hard copy and electronic form in copy number sufficient for individual review by all involved.

The amount of inconvenience and disruption to community residents in conducting the field work must be minimized. Deployment of samplers, sample collection, etc must be co-ordinated such that as much sampling is done concurrently as possible and in as short a time frame as possible most particularly with indoor sampling and urine sampling.

The MOE/technical steering committee may as the study progresses alter some specific detail(s) of a given task where it is in the technical interests of the study.

APPENDIX C

GLOSSARY

APPENDIX C

Glossary

Abiotic - without life; inanimate

ADI – allowable daily intake

Adverse effect – impairment of the natural environment for any use that can be made of it; harm or material discomfort to any person; an adverse effect on the health of any person; impairment of the safety of any person; rendering any property or plant or animal life unfit for use by humans

Ag - silver

ALARA – as low as reasonably achievable

Antagonism - the production of opposing affects

Argyria - skin pigmentation caused by long exposure to or use of preparations of silver.

As (III, V) – Arsenic (trivalent), Arsenic (pentavalent)

Bioavailability - the extent to which a drug, chemical, toxin, after administration, is available to the tissue it is intended to act on

Biotic - pertaining to living organisms.

BTF – Biotransfer Factor – is a ratio of the concentration of the contaminant in the receptor to the concentration in the environmental media

Cancer - loosely, any malignant new growth or tumour; properly, a carcinoma or disorderly growth of epithelial cells which invade adjacent tissue and are frequently spread by the lymphatics and blood vessels to other parts of the body.

Carcinogen - a substance that encourages the growth of cancer

Cardiovascular problems – problems with regards to the heart and blood vessels

CDF – Cumulative Density Function – probability of nonexceedance as a function of a continuous random variable

Chelation therapy - the treatment of heavy metal poisoning or certain other diseases by a substance (chelating agent) which combines chemically with the toxic substances and renders them harmless

Co - cobalt

Concomitant Exposures – more than one exposure occurring at the same time to a chemical agent

Contaminant – means any solid, liquid, gas, odour, heat, sound, vibration, radiation or combination of any of them resulting directly or indirectly from human activities that may cause an adverse effect

Continuous random variable – one that can assume the infinitely large number of values corresponding to the points on a line interval

Continuous variable – a variable that can assume any value on the real axis

Creatine - a nitrogenous compound, ($C_4H_9N_3O_2$), the product of protein metabolism, found in the striped (voluntary) muscle of vertebrates.

Creatinine - dehydrated creatine ($C_4H_7N_3O$) found in urine and muscles.

CRL – Cancer Risk Level – is the predicted risk of an individual in a population of a given size developing cancer over a lifetime

Dermal - pertaining to the skin; consisting of skin

Detection limit – the lowest concentration of a chemical that can be reliably reported to be different from zero

Deterministic modelling - involves the selection of single values, or point estimates, for each of the parameters used in the calculations to arrive at single estimates of risk for the receptors under consideration. This type of modelling tends to maximize the estimated risks as values are chosen from the possible range of values. This usually gives a "worst-case" scenario and may be considered useful to determine the potential relative importance of various exposure pathways and contaminants.

DMA – dimethylarsinic acid

Dose – the amount of chemical taken into the body

Dose-response curve – shows the effects on receptor organisms of defined doses of toxicants

End point – refers to an effect on a human or ecological receptor that can be measured and described in some quantitative fashion

E-PERM – hand held devices used to measure radon concentrations

Environmental media – includes soil, indoor air and dust, outdoor air and dust, drinking water, vegetation

EPA – Environmental Protection Act/Agency

Exposure – means the contact between a contaminant and an individual or population. The exposure may occur through pathways such as ingestion, dermal absorption (contact) or inhalation

Exposure limit – the highest exposure that would not produce adverse affects

Exposure pathway – means the route by which a receptor comes into contact with a contaminant

Exposure ratio – (ER) is a ratio expressed by dividing the predicted exposure to a substance by the exposure limit

Gamma radiation - a penetrating radiation given off by radium and other radioactive substances

Glaucoma - disease of the eye causing pressure within the eyeball leading to a growing dimness of vision

GPS – Global Positioning System

Hazard – means the adverse impact on health or property which results from the presence of or exposure to a substance. In some instances the substance itself is also referred to as the hazard, rather than the adverse impact which the substance causes.

Health risk study - is the qualitative and quantitative determination of estimation of the magnitude, frequency, duration and route of exposure to a particular physical, chemical or biological disturbance in the environment. It delineates major pathways.

Heavy metals – metallic elements, some of which are required in trace concentrations for plant and/or animal nutrition, but which become toxic at higher concentrations

Histogram – bar graph of data

Hydrogeology – a branch of geology, focusing on the study of groundwater

Hyperpigmentation - coloration by pigments in the tissues

IARC – International Agency for Research on Cancer

Ion-exchange - transfer of ions from a solution to a solid or another liquid

Keratosis - a horny growth on or over the skin, eg a wart; a skin condition

LAGS – Large Area Gamma Survey System – an instrument used to perform surface gamma radiation surveys

Leaching – means the process by which contaminants in soil are dissolved and removed by water percolating through the soil

LOAEL – Lowest Observable Adverse Effect Level

masl – meters above sea level

Marginally contaminated site – contamination criteria are above Ontario background levels

Mean – an average amount or value

Median – the middle value position in a series of values

Metaplasia - tissue transformation

MMA – monomethylarsonic

Mode – the value of greatest frequency

Multimedia exposure assessment - is an approach to risk assessment looking at total exposure to a substance through a number of possible pathways, such as air, soil, drinking water and food. To evaluate the health consequences of exposure to a contaminant through a particular pathway or source, it is necessary to understand the total exposure picture of people from all routes.

Musculo-skeletal problems – problems relating to muscles and skeleton

Neurotoxicity - the degree to which a substance is poisonous to nerve tissue; the state caused by exposure to a neurotoxin.

Neurotoxin - a substance poisonous to nerve tissue

Ni - nickel

95th percentile – refers to the point in a population of analysis results which is greater in value than 95 percent of the population and is smaller than 5 percent of the population

NOAEL – no observable adverse effect level – the threshold below which no observable response occurs

Non-carcinogen – substances for which there is a dose below which measurable adverse effects should not occur even if there is a lifetime of exposure

Non-linear system – a mathematical system or process is nonlinear if there are at least two unknown quantities that depend on each other. Density-dependent transport and reactive geochemical transport are common examples. These systems require more computational effort to solve compare with linear systems

NTP – National Toxicology Program

ODWO – Ontario Drinking Water Objectives

OSHA - Occupational Safety and Health Administration

PbB – blood lead level

Pharmacokinetics – the behaviour of a chemical within the body, including absorption or uptake into the body via different routes of exposure, metabolism and distribution of the chemical or its metabolites within the tissues of the body, as well as rates and mechanisms of excretion or elimination from the body

Phytotoxicology – study of the harmfulness of chemicals to plants

Polycythaemia - an excess of red blood corpuscles (cells)

Potentiation – making chemicals more potent or effective (boost their activity) by using them in combination with one another

Precipitation - the separation of suspended matter, the formation or sinking of a precipitate, or the precipitate itself

Probabilistic modelling - tries to capture the effect of variability in location, environmental concentrations and other factors. Input parameters used are distributions

instead of single values, so as to reflect natural variability and uncertainty within a particular category or parameter.

PDF – Probability Density Function – probability distributions for a continuous random variable

Random variable – parameter that cannot be predicted with certainty

Radionuclide - any radioactive atom of an element identified by the number of neutrons and protons in its nucleus, and its energy state.

Receptor – means the person or organism, including plants, subjected to chemical exposure

Reverse osmosis - purification of water by forcing it under pressure through a membrane impermeable to the impurities to be removed

Rfd – reference dose – an estimate of a daily exposure (mg/kg/day) to the general human population, including sensitive sub-groups, that is likely to be without an appreciable risk of deleterious effects during a lifetime of exposure

Risk – is the probability or likelihood that an adverse outcome will be caused by an action or condition. In the context of environmental issues, the actions and conditions of concern usually are associated with the exposure to a chemical or physical agent such as noise, heat or radiation.

Risk assessment - is aimed at determining what the magnitude of exposures may be through various pathways for different subgroups and whether or not adverse or undesirable effects from such chemicals would be expected.

Risk management – is the process of evaluating possible courses of action and selecting among them with the objective of minimizing risks.

RMC – risk management criterion

Sedimentation - to deposit as sediment; to cause or allow to deposit sediment.

SEGH – Society for Environmental Geochemistry and Health

Significantly contaminated site – contamination exceeds provincial clean-up guidelines

Socio-demographic – study of a population's social structure, size, density and distribution

Solidification – forming a solid mass having sufficient structural integrity to allow it to be transported in convenient sized pieces without the need for secondary containment

SSRA – Site Specific Risk Assessment – is a risk assessment which estimates the health risk posed to humans, plants, wildlife and the natural environment from exposure to a contaminant for a specific area

Stabilization – immobilization through a chemical reaction or entrapment in an impermeable and inert structure

Stellite – an alloy of 55% cobalt, 28% chromium and 14% Tungsten

Stochastic analysis – random analysis or a model that contains a random component

Synergism – the increased effect of two substances by using them together

Tailings - refuse, dregs; the rejected or washed away portion of an ore (mineral extraction); the higher boiling fraction in a distillation process

Teratogenicity – means the ability of a chemical to cause a change in the normal development process of an unborn organism, resulting in permanent alterations in the biochemical, physiological or anatomical functions of the organism

Threshold – means the concentration or dose of a chemical below which an adverse impact is not expected to occur

Toxicity – of a chemical depends on the amount of chemical taken into the body and the duration of exposure

Volatilization – means to process by which a chemical converts from a liquid or solid phase into a gaseous phase and disperses into the air

APPENDIX D
CONTOUR MAPS

Figure 2: Concentration Contour Map of Arsenic ($\mu g/g$) in Soil Collected in the Vicinity of the Village of Deloro

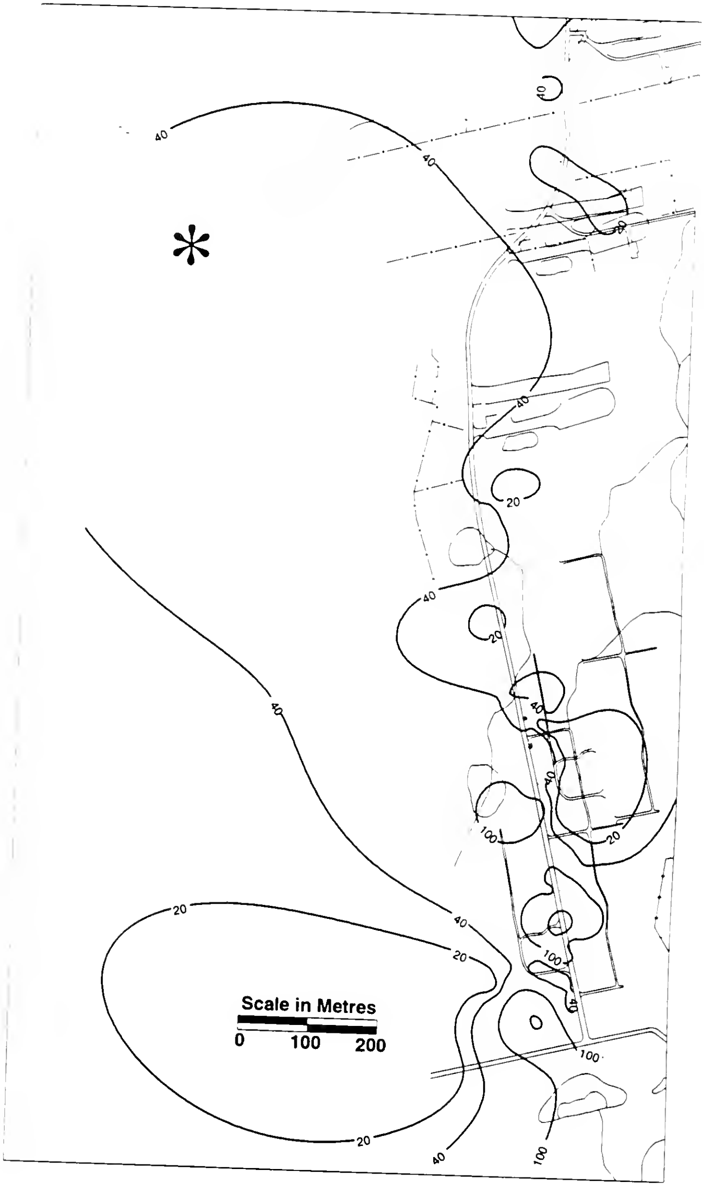


Figure 3: Concentration Contour Map of Cobalt ($\mu g/g$) in Soil Collected in the Vicinity of the Village of Deloro

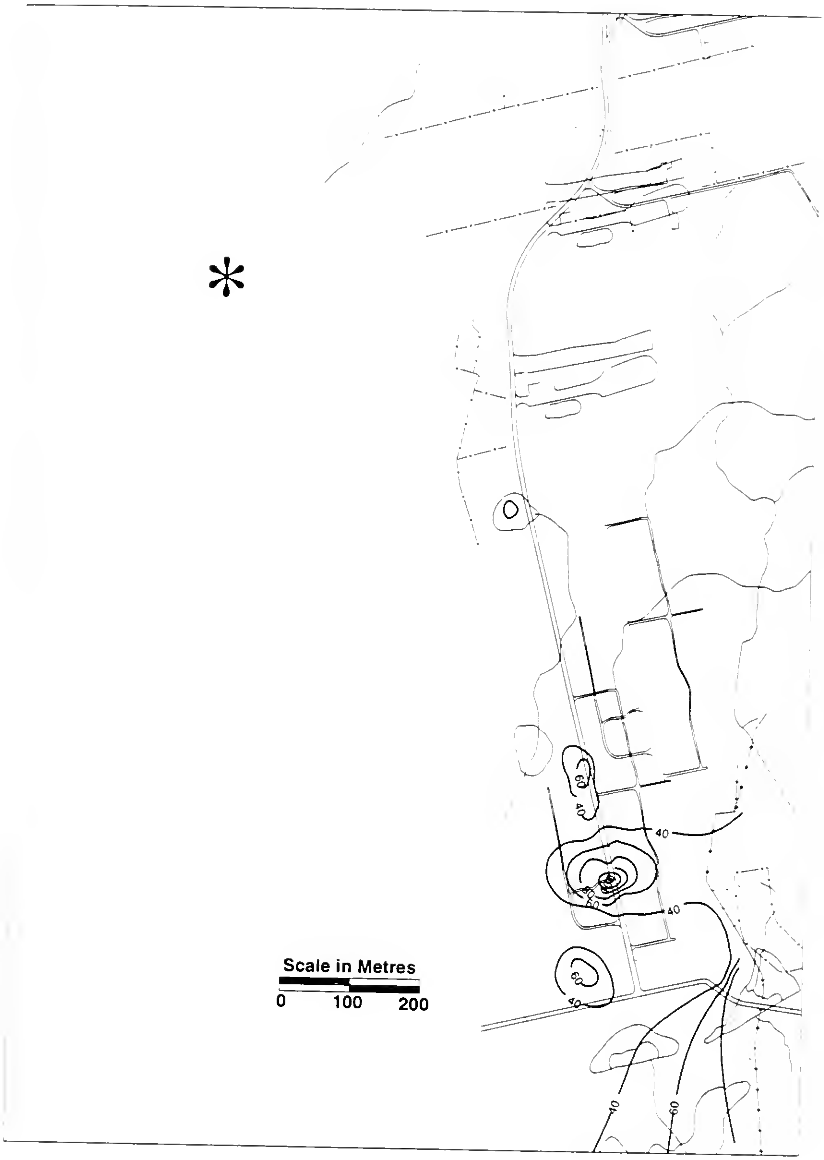


Figure 4: Concentration Contour Map of Lead ($\mu g/g$) in Soil Collected in the Vicinity of the Village of Deloro

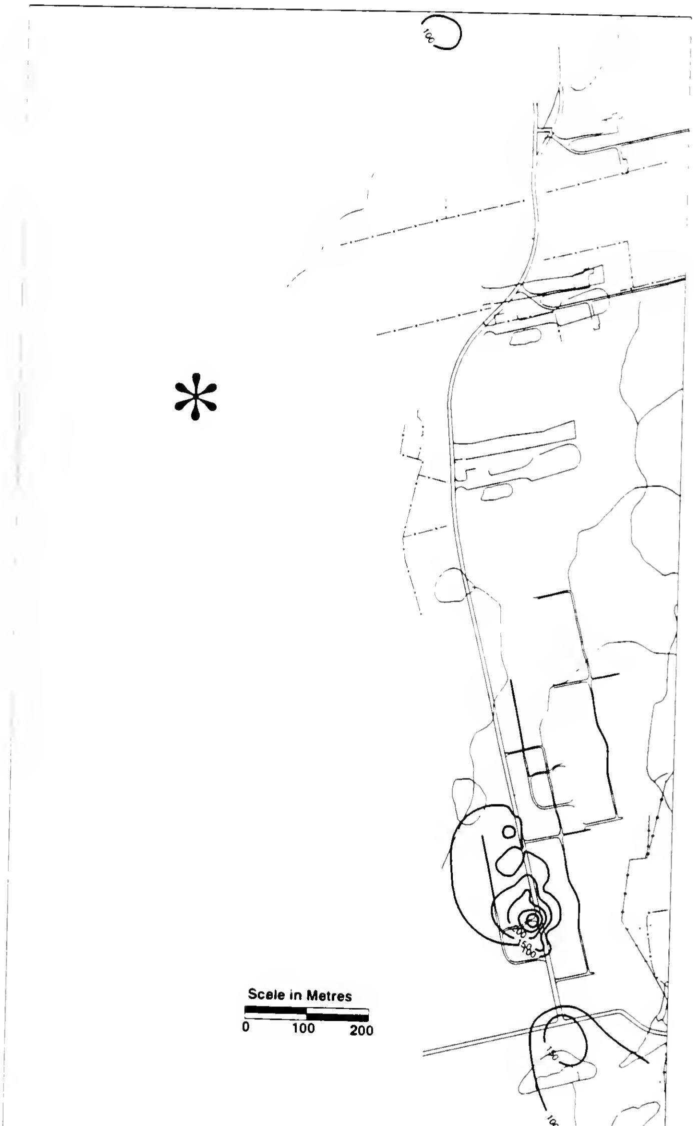


Figure 5: Concentration Contour Map of Nickel ($\mu g/g$) in Soil Collected in the Vicinity of the Village of Deloro

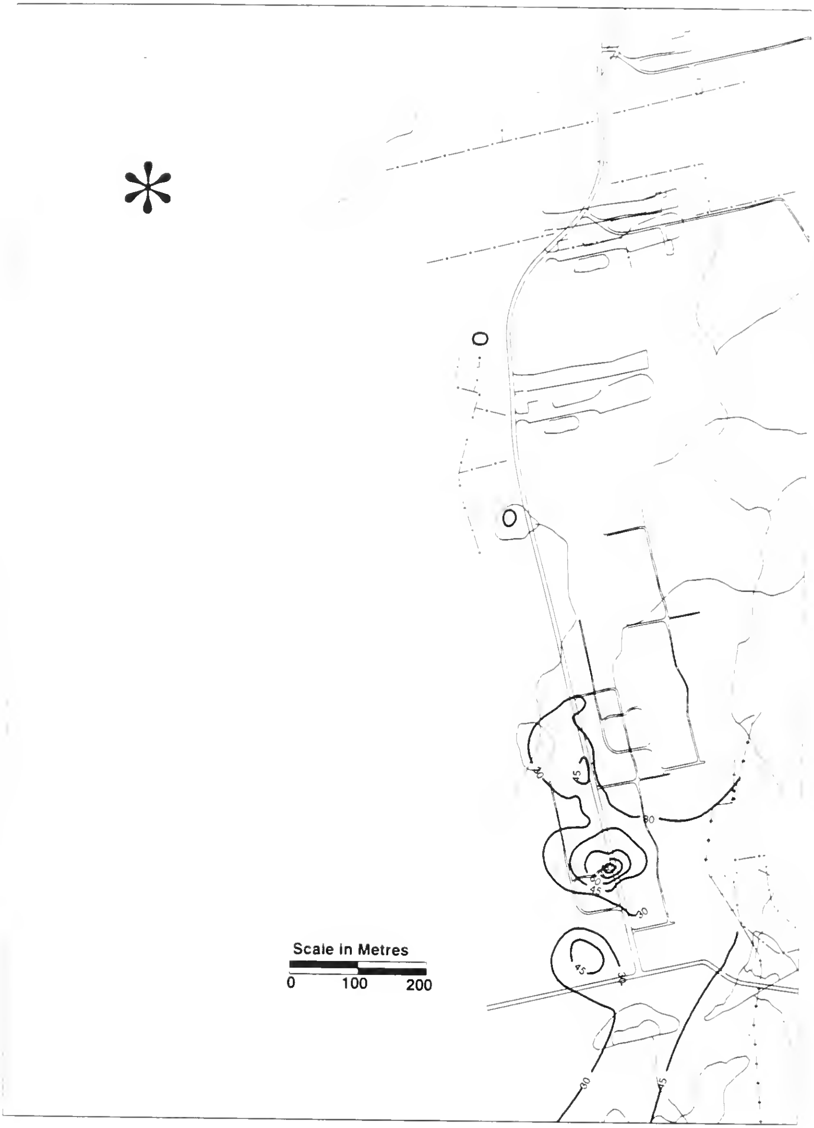
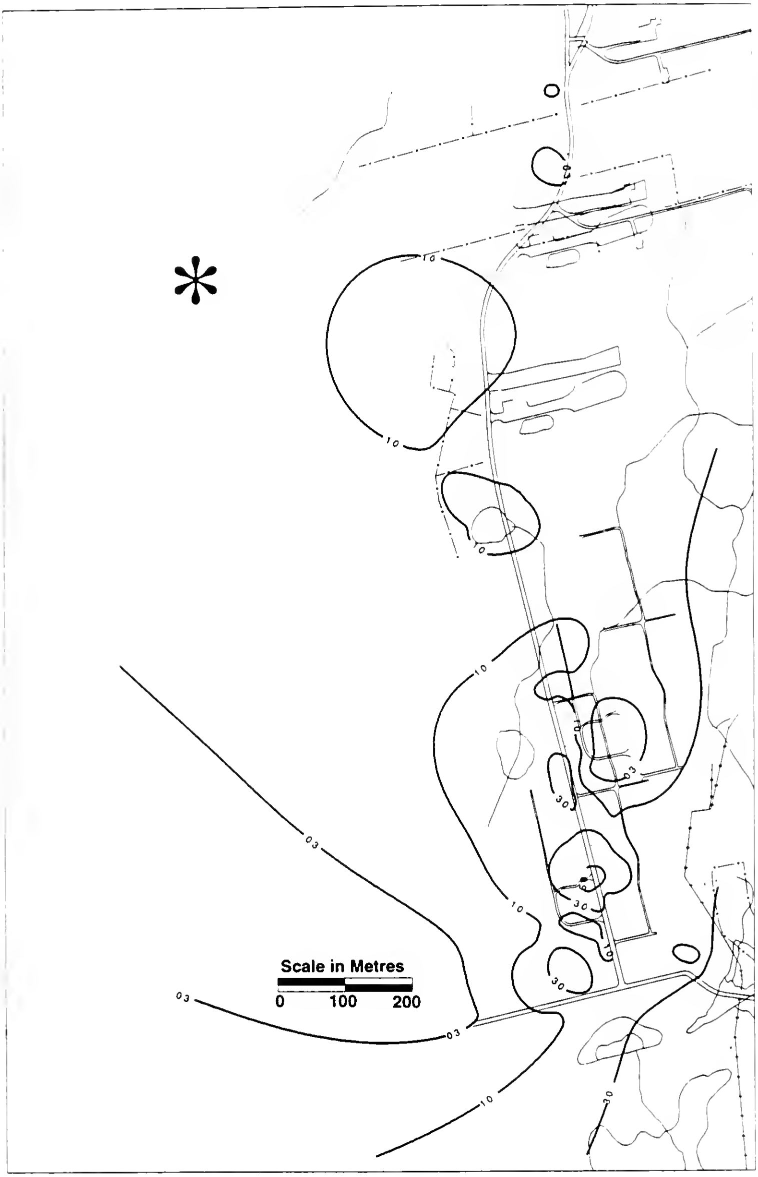


Figure 6: Concentration Contour Map of Silver ($\mu g/g$) in Soil Collected in the Vicinity of the Village of Deloro



SDB-056-3511-1998

APPENDIX E

CHEMICAL TOXICITY INFORMATION

APPENDIX E

Chemical Toxicity Information

Arsenic

Distribution of arsenic within the body is affected by the route through which exposure occurs. Given sufficient time for equilibration, arsenic generally tends to be evenly distributed amongst tissues within the body. The interaction of arsenic with various tissues is dependent on the chemical form of the arsenic. The primary pathway of elimination of inorganic arsenic is excretion via the urine. Because of the importance of urinary excretion as the primary route of elimination of arsenic, concentrations of arsenic compounds in the urine is considered to be a reliable index of recent exposure to arsenic. The calculated daily exposure was applied to an equation developed by Walker and Griffin (1998) in order to predict urinary arsenic concentrations which were then compared to actual urinary data collected by Goss Gilroy (refer to section IV).

Acute effects of oral arsenic exposure include vomiting, nausea, diarrhea, gastrointestinal haemorrhage, and death. The USEPA (1998) calculated an oral RfD of 0.3 μg As/Kg body weight/day based on epidemiological studies of chronic exposure to arsenic through drinking water. This limit was selected for non-carcinogenic effects. Arsenic exposure via the oral route was considered to be carcinogenic to humans, based on the incidence of skin cancers in epidemiological studies examining human exposure through drinking water. The CSF of 0.0015 (μg As/Kg body weight/day)$^{-1}$ and corresponding RSD of 0.00067 μg As/Kg body weight/day based on an acceptable risk level of one-in-one million, was adopted as the oral exposure limit for carcinogenic effects of arsenic for this assessment.

The oral RfD adjusted for bioavailability, was used to assess the non-carcinogenic effects of arsenic via inhalation. The inhalation unit risk value of 0.0043 (μg As/m^3)$^{-1}$ was converted into an inhalation CSF of 0.013 (μg As/Kg body weight/day)$^{-1}$ assuming a 70 kg adult breathes 23 m^3/day.

The USEPA (1998) does not determine exposure limits for dermal exposure; therefore, the oral RfD and oral CSF, adjusted for bioavailability, were used to assess the non-carinogenic and carcinogenic effects, respectively, via dermal exposure.

The oral bioavailability of arsenic compounds is dependent on the chemical species and on the matrix (e.g. soil or dust) in which it is administered. Based on published literature, the absorption of water-soluble inorganic arsenic compounds in an aqueous solution is about 95 percent. For soil and house dust containing arsenic the absorption is about 14 and 19 percent respectively. The bioavailability of inorganic arsenic for exposure via inhalation would be in the range of 30 – 34 percent. The dermal absorption in humans range from 0.8 to 1.9 percent.

Beryllium

Pure beryllium is a hard, grayish, odourless metal. In nature, beryllium can be found in compounds in mineral rocks, coal, soil, and volcanic dust. Beryllium compounds are

commercially mined, and the beryllium is purified for use in electrical parts, machine parts, ceramics, aircraft parts, nuclear weapons, and mirrors.

Exposure to beryllium would most likely occur from breathing contaminated workplace air (e.g. mining or processing ores, alloy and chemical manufacturing with beryllium, machining or recycling metals containing beryllium), breathing tobacco smoke from leaf high in beryllium.

The effects of exposure to beryllium via inhalation depends on how much you are exposed to and for how long. High levels of beryllium in air cause lung damage and a disease that resembles pneumonia. If you stop breathing beryllium dust, the lung damage may heal. Some people become sensitive to beryllium. This is called a hyper-sensitivity or allergy. These individuals develop an inflammatory reaction to low levels of beryllium. This condition is called chronic beryllium disease, and can occur long after exposure to small amounts of beryllium. This disease can make you feel weak and tired, and can cause difficulty in breathing.

Both the short-term, pneumonia-like disease and the chronic beryllium disease can cause death.

Swallowing beryllium has not been reported to cause effects in humans because very little beryllium can move from the stomach and intestines into the bloodstream.

Beryllium contact with scraped or cut skin can cause rashes or ulcers.

The Department of Health and Human Services (DHHS) has determined that beryllium and certain beryllium compounds may reasonably be anticipated to be carcinogens. This determination is based on animal studies and studies in workers. None of the studies provide conclusive evidence, but when taken as a whole, they indicate that long-term exposure to beryllium in the air results in an increase in lung cancer.

The Environmental Protection Agency (EPA) restricts the amount of beryllium that industries may emit into the environment to 10 grams (g) in a 24-hour period, or to an amount that would result in atmospheric levels of 0.01 micrograms of beryllium per cubic metre of air (0.01 $\mu g/m^3$), averaged over a 30-day period. The National Institute for Occupational Safety and Health (NIOSH) recommends a standard for occupational exposure of 0.5 $\mu g/m^3$ of beryllium in workroom air during an 8-hour shift to protect workers from potential cancer. The Occupational Safety and Health Administration (OSHA) sets a limit of 2 $\mu g/m^3$ of beryllium in workroom air for an 8-hour work shift.

Beryllium dust settles from air to the soil and water. It also enters water from rocks and soil, and from industrial waste. Some beryllium compounds dissolve in water, but most settle to the bottom as particles. Fish do not build up beryllium in their bodies from the surrounding water to any great extent.

Boron

Boron is a compound that occurs in nature. It is often found combined with other sub-stances to form compounds called borates. Several companies in the United States produce most of the world's borates by processing boron compounds. Borates are primarily used to produce glass. They are also used in fire retardants, leather tanning

industries, cosmetics, photographic materials, soaps and cleaners, some pesticides and wood preservatives, and for high-energy fuel.

Boron and its compounds are usually found in air, water, and food at low levels. It can be found at high levels in drinking water from areas where it is found at naturally high levels in the earth.

There is little information on the health effects of long-term exposure to boron. Most of the studies are on short-term exposures. Breathing moderate levels of boron can result in irritation of the nose, throat, and eyes. Reproductive effects, such as low sperm count, were seen in men exposed to boron over the long-term. Animal studies have shown effects on the lungs from breathing high levels of boron. Ingesting large amounts of boron over short periods of time can harm the stomach, intestines, liver, kidney, and brain. Animal studies of ingestion of boron found effects on the testes in male animals. Birth defects were also seen in the offspring of female animals exposed during pregnancy. Effects of human skin contact with boron is unknown. Animal studies have found skin irritation when boron was applied directly to the skin.

The Department of Health and Human Services, the International Agency for Research on Cancer, and the Environmental Protection Agency (EPA) have not classified boron as to its human carcinogenicity. One animal study found no evidence of cancer after lifetime exposure to boric acid in food. No human studies are available.

The Occupational Safety and Health Administration (OSHA) has set an occupational exposure limit of 15 milligrams per cubic meter (15 mg/m^3) for boron oxide dust in workplace air for an 8-hour workday, 40-hour workweek. The National Institute for Occupational Safety and Health (NIOSH) currently recommends an occupational exposure limit of 10 mg/m^3 for boron oxide dust. NIOSH also recommends that 25 ppm boron trifluoride be considered immediately dangerous to life and health. This is the exposure level of a chemical that is likely to cause permanent health problems or death.

No information is available on how long boron remains in air, water, or soil. It does not appear to accumulate in fish or other organisms in water, however it does accumulate in plants, and is found in foods such as fruits and vegetables.

Cadmium

Cadmium is a natural element that is usually found as a mineral combined with other elements such as oxygen, chloride, and sulphur. Cadmium forms both organic and inorganic compounds. It is extracted mostly during the production of other metals, and is used in batteries, pigments, metal coatings, and plastics.

Cadmium and cadmium compounds possess moderate acute toxicity via both ingestion and inhalation. Cadmium is slowly excreted by the body, and therefore bioaccumulates in humans. Severe toxic effects can be caused due to chronic human exposure. The route of entry for cadmium with the most immediate health effects is inhalation of fumes or dust. Local health effects caused by cadmium exposure include irritation to the respiratory tract and to the mucous membrane lining of the inner surface of the eyelid. Prolonged exposure may result in anosmia (loss of sense of smell) and discolouration of the teeth. A systemic effect of cadmium inhalation is severe pulmonary irritation. This is often accompanied my dyspnea (severe difficulty in breathing) and general weakness.

Troubled breathing may become more pronounced as pulmonary adema and tracheo-bronchitis develop. The most common result of acute systemic cadmium exposure is emphysema, but in some instances, mortality may occur.

Chronic cadmium poisoning can be associated with both inhalation and ingestion. Cadmium fumes and dust inhaled, but not absorbed into the body usually results in damage to the respiratory tract. However, cadmium absorbed into the body through inhalation or ingestion can result in anemia, obstructive pulmonary disease, and chronic renal tubular diseases. These problems may lead to the formation of renal caluli.

The Department of Health and Human Services (DHHS) has determined that cadmium and its compounds may reasonably be anticipated to be carcinogens. This is based on weak evidence of increased lung cancer in humans from breathing cadmium, and on strong evidence of this from animal studies. No evidence exists that links ingestion or absorption of cadmium to the occurrence of cancer.

OSHA's occupational exposure limits for cadmium fumes and dust are 100 $\mu g/m^3$ and 200 $\mu g/m^3$, respectively, however OSHA plans to limit all cadmium compounds to either 1 or 5 $\mu g/m^3$. The National Institute for Occupational Safety and Health (NIOSH) recommends that workers breathe as little cadmium as possible.

Sorption, bioaccumulation and biotransformation are the major environmental fate processes of cadmium. Adsorption and desorption processes in soils and sediments cause most of the movement of cadmium in the environment. These processes are significantly affected by the media pH levels. The solubility of cadmium is dependent on both water quality and the nature of the cadmium complex involved. Cadmium can travel for long periods of time in air.

Cobalt

Cobalt is an essential micronutrient in humans, as it is a required element in hydroxycobalamin (vitamin B12). Acute effects of exposure to cobalt-containing dust are typically inflammation of the nasopharynx. Contact dermatitis has also been consistently reported upon acute dermal exposure to cobalt compounds.

There is insufficient evidence to implicate cobalt or cobalt compounds as human carcinogens. Cobalt and its compounds presently have an IARC classification of 2B; possible carcinogenic to humans.

The USEPA Region III derived an oral RfD of 60 g/kg body weight/day for cobalt based on cobalt intake levels in food (USEPA, 1997). This RfD was based on the upper range of average intake for children (60 g/kg/day), that is below the levels of cobalt needed to induce polycythemia in both renally compromised patients (180 g/kg body weight/day) and normal patients (960 g/kg body weight/day). However, the current USEPA IRIS list of chemicals does not include cobalt (USEPA, 1998).

An inhalation RfD of 0.01 g/kg body weight/day is proposed by the Agency for Toxic Substances and Disease Registry (ATSDR, 1997) of the US Public Health Service. This inhalation RfD was derived by ATSDR based on the NTP (1991) and Bucher *et al.* (1990) studies, where a LOAEL of 0.3 mg/m^3 was identified, based on metaplasia of the larynx in rats and mice.

No regulatory dermal exposure limits were identified in the literature reviewed for the current assessment. Therefore the bioavailable adjusted oral RfD was use for dermal exposure.

For the purposes of this assessment, the human bioavailability of cobalt was assumed to be 18 to 97 percent for ingestion, 24 to 71 percent for inhalation and 0.06 percent for dermal exposures.

Copper

Copper is a natural element that is also an essential nutrient for the human body. It is used as a conductive agent, reducing agent, catalyst, and as wire material, and can be found in some pesticides.

Copper can be ingested from drinking water or eating certain foods. Another possible route of exposure includes the inhalation of roadway dust containing copper from the use of car brakes. It could also be ingested from foods that have absorbed it from copper cookware.

According to the Environmental Defense Fund, copper is ranked as one of the most hazardous compounds (i.e. within the worst 10 percent) to ecosystems and human health. It is a suspected cardiovascular or blood toxicant, developmental toxicant, gastrointestinal or liver toxicant, and reproductive toxicant. Copper and its compounds are a suspected respiratory toxicant, and can produce a variety of acute and chronic pulmonary conditions including local irritation, bronchitis, pulmonary edema, and emphysema. Chronic copper poisoning is very rare, since the capacity for healthy human livers to excrete copper is considerable. Any reports of chronic copper poisoning that do exist involve patients with liver disease.

No human carcinogenicity data, and inadequate animal carcinogenicity data is available to classifiy copper as a carcinogen.

Lead

The potential for lead to impair neurobehavioural development in childrne is the suject of much concern. However, because of the complexity of mental development processes, and sensitivity of testing methods, it is not possible to make definitive conclusions regarding potential adverse effects associated with blood lead levels (PbB) of less than 25 µg/dL.

The USEPA (1998) has classified lead as a probable human carcinogen based on sufficient animal evidence. However, the Carcinogen Assessment Group (USEPA, 1998) did not recommend derivation of a quantitative estimate of oral carcinogenic risk, due to a lack of understanding pertaining to the toxicological and pharmacokinetic characteristics of lead. In addition, the neurobehavioural effects of lead in children were considered to be the most relevant endpoint in determining an exposure limit.

Health Canada (1996) recommended a provisional tolerable daily intake (PTDI) for lead of 3.57 g/kg body weight/day. This value was based on technical reports from annual meetings of the Joint FAO/WHO Expert Committee on Food Additives (JEFCA), and epidemiological studies associating lead exposure with neurological effects in infants and children.

The Ontario Ministry of the Environment and Energy recommended an IOC_{pop} (intake of concern for populations) of 1.85 g/kg body weight/day which incorporated the population-based significance of the health effects and attempted to minimize the predicted number of children with individual blood lead levels of concern (OMOE, 1996). Subclinical neurobehavioural and developmental effects were the critical effects appearing at the lowest levels of exposure (OMOE, 1994). The IOC_{pop} was based on an LOAEL in infants and young children of 10 g/dL, converted to an intake, with an applied uncertainty factor of 2 for the use of an LOAEL (OMOE, 1994). Because the IOC_{pop} was intended for the entire population and independent of route of exposure, 1.85 g/kg body weight/day was adopted for both oral and inhalation exposure limits for the current assessment.

For the purpose of this assessment, the human bioavailability was assumed to be 10 to 15 percent for adults, and 42 to 53 percent for children/adolescents for ingestion, 19 to 22 percent for adults, and 38.2 to 44.8 percent for children/adolescents for inhalation, and 0.06 percent for dermal exposure.

Mercury

Mercury is a naturally occurring metal which can have several forms. Elemental mercury is a shiny, silver-white, odourless liquid. When heated it becomes a colourless, odourless gas. Several forms of mercury including insoluble elemental mercury, inorganic species, and organic species, can exist in the environment. Mercury has a very low viscosity and high surface tension. It is contained in a variety of products including thermometers, dental fillings, batteries and antiseptic creams. It is also used in the production of chlorine gas and caustic soda. In some industries it is used as a heat transferring agent or an electrode material.

Exposure to mercury can affect human health via inhalation, ingestion, or absorption through the skin. Elemental mercury's volatility and toxicity can be very harmful since it can release enough vapour even at room temperature to reach dangerous levels in unventilated areas. Exposure to mercury may take place through inhalation of dusts, mercury compounds or dust particles to which mercury vapour has adhered. Small dust particles with a diameter less than five micrometers are particularly hazardous as they can be inhaled deeply into the lungs. Mercury is an irritant to the skin and to the mucous membranes. It may also be a cause of conjunctivitis. Acute mercury poisoning may affect the lungs in the from of interstitial pneumonitis, bronchitis, and bronchiolitis with pulmonary edema. Pharyngitis, dysphagia (difficulty in swallowing), and nausea may ensue. Delayed effects consist of nephritis (inflammation of the kidneys) and hepatitis. Chronic exposure to mercury produces four classical signs: gingivitis, sialorrhea, increased irritability, and muscle tremors. Beyond these effects, renal failure may occur with prolonged exposure. Within the central nervous system, chronic exposure may result in personality changes, delirium, fatigue, memory loss, and hallucinations.

Human exposure to mercury can cause brain or kidney damage, and also damage to developing fetus; the amount of intake and the exposure rates may be critical determinants of actual health impacts. For mercury, exposure is more likely to be via ingestion of fish with bioaccumulated levels of this chemical.

Mercury has not been classified as to its human carcinogenicity because of lack of data from studies on people and laboratory animals.

Elementary mercury is not as toxic as an acute poison. However, inhalation of high concentrations of mercury vapour can cause pnemonitis, bronchitis, chest pains, dyspena, coughing, stomatitis, gingivitis, salivation , and diarrhea. Soluble mercuric salts are highly poisonous on ingestion, with oral LD_{50} values of 20 to 60 mgkg reported. The Occupational Safety and Health Administration (OSHA) permissible occupational exposure limit is 0.1 μg/m^3 for any period of time.

Hg is highly bioaccumulative and persistent in the environment. Adsorption onto suspended and bed sediments is probably the most important process determining the fate of mercury in the aquatic environment. Mercury sorbs most strongly to organic materials, and mercury in soils is often complexed to organic compounds. Mercury is strongly bioaccumulated by numerous mechanisms. Methylmercury is the most readily accumulated and retained form of mercury in aquatic biota, and once it enters a biological system it is very difficult to eliminate.

Nickel

Nickel is an essential element in humans and generally exceeds dietary requirements. Acute oral exposure to nickel compounds can result in flare-ups of allergic contact dermatitis and eczema. A review of studies associated with nickel mining, smelting, refining and high nickel alloy manufacturing in general showed increased risks for lung and nasal cancers with occupational inhalation exposures.

Nickel refinery dusts and nickel subsulfide are both classified by the USEPA as A: human carcinogens. Only inhalation unit risk values for these substances are available. For nickel refinery dusts, the inhalation unit risk is 2.4×10^{-4} (μg/m^3)$^{-1}$, which corresponds to a RSD of 0.00073 per μg/kg body weight/day (assuming a breathing rate of 23 m^3/day and a body weight of 70 kg) (USEPA, 1998). For nickel subsulfide (a major component of nickel refinery dust), the inhalation unit risk is 4.8×10^{-4} (μg/m^3)$^{-1}$, which corresponds to a RSD of 0.0015 per μg/kg body weight/day (assuming a breathing rate of 23 m^3/day and a body weight of 70 kg) (USEPA, 1998). To date, chronic non-cancer oral and inhalation exposure limits for these substances have not been derived by any jurisdiction in the U.S. However, Health Canada (1996) reports a non-cancer tolerable inhalation concentration of 0.018 μg/m^3 for nickel subsulfide. Assuming a breathing rate of 23 m^3/day and a body weight of 70 kg, this air concentration would correspond to a tolerable dose of 0.006 μg/kg body weight/day.

While some jurisdictions consider soluble nickel compounds to be human carcinogens (i.e. Health Canada), the available evidence suggests that these compounds behave as threshold chemicals; thus the exposure limit is expressed as an RfD. The USEPA (1986; 1998) recommended an oral RfD of 20 μg/kg body weight/day for soluble salts of nickel based on rat data from the Ambrose *et al.* (1976) study.

For nickel sulphate, Health Canada (1996) derived a Chronic Daily Intake (CDI) of 50 μg/kg body weight/day, based on the NOAEL from the Ambrose *et al.* (1976) and using an uncertainty factor of 100 (10-fold for interspecies extrapolation, 10-fold for interspecies variation). Unlike, the USEPA, Health Canada did consider an additional uncertainty factor for design limitations necessary. For the inhalation route, Health

Canada (1996) recommends a tolerable inhalation concentration (non-cancer effects) of 0.0035 μg/m^3 for nickel sulphate. Assuming a breathing rate of 23 m^3/day and a body weight of 70 kg, this air concentration would correspond to a dose of 0.0012 μg/kg body weight/day. The RfD was based on lung and nasal lesions in rats and mice observed by Dunnick *et al.* (1989).

Nickel oxide is also considered to behave as a threshold substance. However, no regulatory exposure limits have been derived for the oral or inhalation routes by U.S. agencies (ITER, 1998). Health Canada (1996) recommends a tolerable inhalation concentration (non-cancer effects) of 0.02 μg/m^3. Assuming a breathing rate of 23 m^3/day and a body weight of 70 kg, this air concentration would correspond to a dose of 0.007 μg/kg body weight/day. Health Canada has not derived a chronic oral exposure limit for nickel oxide.

No oral or inhalation, cancer or non-cancer regulatory exposure limits for metallic nickel were identified in the literature reviewed for the current assessment, although Health Canada (1996) reports a provisional non-cancer tolerable concentration (inhalation) of 0.018 μg/m^3. Assuming a breathing rate of 23 m^3/day and a body weight of 70 kg, this air concentration would correspond to a dose of 0.006 μg/kg body weight/day.

With respect to inhalation exposures of nickel compounds in general, the Ontario Ministry of the Environment (OMOE) recommends a 24-h reference concentration (RfC) of 2 μg/m^3 as an acute exposure limit for nickel compounds (OMOE, 1994). The only chronic regulatory inhalation exposure limit identified for nickel is a Minimal Risk Level (MRL) of 0.2 μg/m^3 (ATSDR, 1998), which when expressed as a dose is equal to 0.07 μg/kg body weight/day (assuming a breathing rate of 23 m^3/day and a body weight of 70 kg).

No regulatory dermal exposure limits for nickel compounds were identified in the literature reviewed for the current assessment.

For the purposes of this assessment, the human bioavailability of nickel was assumed to be 1 to 10 percent for ingestion, 13.6 to 19 percent for inhalation, and 0.06 percent for dermal exposures. Given that the sole source of nickel refining dust and nickel subsulfide is nickel refining operations (ATSDR, 1998), it is not possible that the nickel on site is in either of these forms; therefore, these limits were not used in the current assessment. Therefore, only the most conservative non-carcinogenic endpoints for nickel were considered for this assessment. The RfDs of 1.3 and 0.0012 μg Ni/kg body weight/day for nickel chloride and nickel sulfate, respectively, were adopted as the oral and inhalation exposure limits, respectively, for the current assessment of nickel toxicity.

Silver

Silver is considered to be non-carcinogenic in both laboratory animals and humans. Silver compounds have been used in medicine for centuries. The primary effect that has been observed in humans exposed to silver *via* therapeutic treatments has been argyria (USEPA, 1985). Argyria results from the deposition of silver in the dermis and from silver-induced production of melanin, and although permanent, is not associated with any adverse human health effects (USEPA, 1998).

The silver oral exposure limit used in this assessment is the oral reference dose (RfD) of 5 µg/kg body weight/day (USEPA, 1998). The USEPA derived this oral RfD based on data from the Gaul and Staud (1935) argyria study. The endpoint is a cosmetic rather than an adverse health effect associated with a gray discolouration of the skin as a result of the development of argyria.

Neither Health Canada nor USEPA exposure limits were available for inhalation exposure to silver. The American Conference of Governmental Industrial Hygienists (ACGIH, 1998) recommended a time weight average (TWA) threshold limit value (TLV) of 0.1 mg/m^3 for occupational exposure to silver metal. The TWA-TLV was amortized from an 8-hour workday, 5-day workweek, to an exposure limit of 0.8 µg/kg body weight/day, assuming a 70 kg person breathing 23 m^3/day (Curry *et al.*, 1993) is chronically exposed for 24 hours per day, 7 days per week [0.1 mg/m^3 x 23 m^3/day x 1/70 kg x 1,000 µg/mg x 8 h/24 h x 5 days/7 days x 1/10 for non-cognisant exposure]. The safety factor of 10 was considered adequate because the oral RfD adjusted by the inhalation bioavailability is similar in magnitude (5 µg/kg body weight/day x 4 percent); also, the critical effect (argyria) is medically benign (USEPA, 1998). The inhalation exposure limit of 0.8 µg/kg body weight/day for silver derived by CANTOX from ACGIH (1998) was adopted for this assessment.

No data on dermal exposure limits for silver were identified in the literature reviewed for the current assessment.

For the purposes of this assessment, the bioavailability of silver was assumed to be 4 percent for ingestion, 15.4 percent for inhalation, and 1 percent for dermal exposures.

APPENDIX F

TRESPASSER SCENARIO RISK DATA

Supplementary Trespasser Scenario for Metals Exposure on the Mine Site

In evaluating the onsite data, an additional five metals (beryllium, boron, cadmium, copper, and mercury) were found to be present on the Deloro Mine Site at concentrations in excess of the applied guideline criteria. These contaminants are supplementary to the five detected in the village (arsenic, cobalt, lead, nickel, and silver) that were retained for both the offsite and the onsite trespasser scenario previously discussed. While it is not anticipated that a resident of Deloro would be exposed to these five additional inorganic parameters on a regular basis, a trespasser on the site may have an opportunity to come in contact with any of these contaminants in addition to the original five that were evaluated by CANTOX. This section provides a supplementary health risk evaluation of these additional metals based on the trespasser scenario.

Exposure Assessment

CANTOX created a model to evaluate the exposure and risk due to the activity in and about the Village of Deloro for residents of Deloro. This original spreadsheet model was used to calculate the exposure and risk to a trespasser due to coming in contact with the additional five inorganic parameters present on the mine site. The time spent trespassing was kept consistent with the initial scenario, and two hours per week was used as both the mean and maximum time spent onsite.

The soil concentrations that were used in the trespasser scenario calculations were obtained in the same manner as the original five study parameters in the CANTOX report. The plausible maximum and average concentrations were for the mine site Industrial Area, including only soil sample results and excluding any waste materials on the mine site.

Outdoor air concentration data were not obtained on the mine site or in the village for beryllium, boron, cadmium, copper, or mercury. Air concentration values are necessary to determine risk due to inhalation exposure. Outdoor air concentrations were recorded at detectable concentrations in the village for arsenic and nickel. The ratios of onsite soil concentration to outdoor air concentration were compared for both arsenic and nickel. The averages of these ratios, for the maximum plausible concentration and for the typical mean concentration, respectively, were used to determine the outdoor air concentration for the additional metals used in the trespasser scenario. This may result in an over-estimation of the concentration, considering that three of the five onsite metals were not detectable in the outdoor air. Taking the average of the measurable concentrations results in a more conservative estimate.

Hazard Assessment

A discussion of the toxicity and fate and transport properties associated with the boron, beryllium, cadmium, copper, and mercury is provided in Appendix E. CANTOX's model incorporated the trespasser scenario as part of a complete exposure pathway assessment, which also included time spent in the village and background exposures. The trespasser pathway could be separated from the complete pathway, and risk due to trespassing on the mine site

could be reported as a separate value. As the trespasser scenario was the only exposure pathway of interest for the additional five inorganic parameters, 20 percent of the reference dose (RfD) value was used in accordance with the MOE Guideline for Use at Contaminated Sites in Ontario, February 1997. RfDs and cancer slope factors (CSF) were obtained from various sources. An inhalation RfD was not available for copper. A similar methodology to what was used in the CANTOX report for inhalation exposure to silver was implemented. A time weighted average exposure value for copper (dusts and mists) of 1 mg/m^3 was obtained from the 1996 Ontario Occupational Health and Safety Act. This value was then amortized according to the assumptions made by CANTOX, and an inhalation exposure limit of 7.8 µg/kg-body weight/day for copper was derived and used in the risk calculations. A complete list of RfD and CSF values used and their references is provided in Table G.1.

TABLE G.1
SUMMARY OF EXPOSURE LIMITS FOR HUMAN HEALTH RISK ASSESSMENT

Chemical	Rate	Toxicological Criterion		Source
		Type	Value	
Beryllium (non-carcinogenic)	Oral Inhalation	RfD RfD	5×10^{-3} mg/kg-d 5.7×10^{-7} mg/kg-d	IRIS Region 1X (1999)
Beryllium (carcinogenic)	Oral Inhalation	CsF CsF	4.3 $(g/kg)^{-1}$ 8 4 $(mg/kg\text{-}d)^{-1}$	IRIS Region 1X (1999)
Boron	Oral Inhalation	RfD RfD	0.09 mg/kg-d 5.7 x 10-3 mg/kg-d	IRIS Region 1X (1999)
Cadmium (non-carcinogenic)	Oral Inhalation	RfD RfD	5 x 10-4 mg/kg-d 5.71 x 10-5 mg/kg-d	IRIS Region 1X (1999)
Cadmium (carcinogenic)	Oral Inhalation	* CsF	 6.3 $(mg/kg\text{-}d)^{-1}$	- Region 1X (1999)
Copper	Oral Inhalation	RfD RfD	0.037 mg/kg-d 0.008 mg/kg-d	Heast OH&S
Mercury	Oral Inhalation	RfD RfD	3 x 10-4 mg/kg-d 8.57 x 10-5 mg/kg-d	Heast Region 1X (1999)

*Not a carcinogen through this exposure rate.

Bioavailabilities of the inorganic parameters and associated references are available in Table G.2.

Risk Characterization

Table G.3 provides the results of the model as it was applied to only the trespasser scenario for all ten contaminants that are present on the mine site. Of the supplementary contaminants, the cancer risk levels for the carcinogenic effects of beryllium and cadmium were both smaller than the one in one million that was used as the comparison. The exposure ratios for all five inorganic parameters were less than one. Therefore, contributions of trespasser exposures to mean and maximum predicted risks for all metals of interest with the exception of arsenic was negligible. The composite receptor CRL values are displayed, as it is this receptor that portrays the total risk over a lifetime. The preschool child is the receptor whose ER values are shown. The infant receptor is typically more sensitive, but there are no concrete hand-to-mouth exposure data for the infant, and little opportunity to be in contact with soil. Presenting the

TABLE G.2
BIOAVAILABILITY VALUES

Compound	Oral (%)	Reference	Inhalation (%)	Reference	Dermal (%)	Reference
Beryllium	1	Hyslop *et al* 1943; Crowley *et al.* 1949; Furchner *et al.* 1973, Watanabe *et al* 1985	13 6	APD[a]	0 06	Assumed[b]
Boron	100	Underwood 1977; Snyder *et al* 1975	73	APD[a]	0 06	Assumed[b]
Cadmium	0 7-15 6	McLellan *et al.* 1978	13-22	APD[a]	0.5-1	US EPA 1978, CEC 1978; Carson *et al.* 1986; Westar *et al* 1992
Copper	32-78.6	Weber *et al.* 1969, Johnson *et al.* 1992	32-60	APD[a]	3.3	Walker *et al.* 1977
Mercury	40	Morcillo and Santamaria 1995	37	APD[a]	0 06	Assumed[b]

[a]Value based on Airborne Particle Dynamics (APD) (see Task Group on Lung Dynamics, 1966; Brain and Mosier, 1980)
[b]Assumed to behave in a fashion similar to lead (see Moore *et al* 1980)

findings due to infant exposure may result in an over-conservative estimate with the infant falsely showing the highest sensitivity. As the data on the preschool child are the most reliable, these are the values presented.

TABLE G.3
CANCER RISK LEVELS AND EXPOSURE RATIOS FOR THE TRESPASSER SCENARIO

Contaminant	Cancer Risk Level (Composite Receptor)		Exposure Ratio (Preschool Child Receptor)	
	Mean	Maximum	Mean	Maximum
Arsenic	64E-05	60E-04	0 41	5.7
Beryllium	1.5E-07	8.2E-07	0.0000107	0.000486
Boron	–	–	0.000012	0.000028
Cadmium	2.9E-11	5.7E-11	0.0227	0.417
Cobalt	–	–	0.0001	0 0004
Copper	–	–	0.0057	0.0406
Lead	–	–	0 044	0.1
Mercury	–	–	0.00848	0.0588
Nickel	–	–	0.003	0.01
Silver	–	–	0.0002	0.001

Notes.
Denotes Cancer Risk Level not applicable as the contaminant is a non-carcinogen. Arsenic, cobalt, lead, nickel, and silver values were calculated by CANTOX in their report titled "Deloro Village Exposure Assessment and Health Risk Study for Arsenic and Other Metals" Beryllium, boron, cadmium, copper, and mercury values were calculated by CG&S using CANTOX's spreadsheet model.

A	B	C
HUMAN RECEPTOR PARAMETERS		
GENDER (combined)		**COMBINE**
AGE CLASS		
SCENARIO		plausible m
EXPOSURE PARAMETERS	UNITS	
Body weight	kg	8 20E+0C
Area of Exposed Skin - summer days	m^2	2 64E-01
Area of Exposed Skin - winter days	m^2	1 07E-01
Whole Body Surface Area	m^2	4 57E-01
Soil Adherence Factor	g/m^2/d	1 00E+01
Total Amount of Soil & Dust Ingested	g/day	2 00E-01
Percentage of ingestion exposure via indoor dust	unitless	5.50E-01
Percentage of ingestion exposure via outdoor soil	unitless	4 50E-01
Amount of Air Inhaled	m^3/day	3 20E+0C
Amount of time spent outdoors in Deloro - winter	hrs/wk	12.25
Amount of time spent outdoors in Deloro - summer	hrs/wk	18.38
Amount of time spent indoors in Deloro- winter	hrs/wk	134 75
Amount of time spent indoors in Deloro - summer	hrs/wk	128 63
Amount of time on-site (trespasser) - winter	hrs/wk	2 00
Amount of time on-site (trespasser) - summer	hrs/wk	2 00
Amount of time spent in Deloro for any given Season	hrs/wk	147 01
Fraction of time that is summer	unitless	6 70E-01
Fraction of time that is winter	unitless	3 30E-01
Fraction of Produce from Home Garden	unitless	0 00E+0C
Fraction of Fruit and Juices consumed	unitless	0.00E+0C
Amount of Water Consumed	L/day	6.77E-01
Amount of Fruit end Juices consumed	g/day	3.16E+02
Amount of Root Vegetables Consumed	g/day	1.92E+02
Amount of Other Vegetables Consumed	g/day	1.81E+02
Estimated Urinary Output	l/day	2 40E-01
Fraction of Inorganic Arsenic excreted daily	unitless	6 00E-01
Age class duration	yr	5 00E-01
Entire Lifespan	yr	7 00E+01
Carcinogenetic Amortization Factor	unitless	7 14E-03
CALCULATED VALUES		
Time spent outdoors in the village-winter	unitless	2.01E-02
Time spent outdoors in the village - summer	unitless	6.53E-02
Time spent indoors at home - winter	unitless	2.65E-01
Time spent indoors et home - summer	unitless	5.13E-01
Amount of time on-site (trespasser) - winter	unitless	3 93E-03
Amout of time on-site (trespasser) - summer	untiless	7 98E-03
BACKGROUND EXPOSRUE PARAMETERS		
Amount of time spent outdoors - winter	hrs/wk	1 40E+01
Amount of time spent outdoors - summer	hrs/wk	2 10E+01
Amount of time spent indoors - winter	hrs/wk	1.54E+02
Amount of tme spent indoors - summer	hrs/wk	1.47E+02
Total amount of time accumulated in one week	hrs/wk	1.68E+02
Fraction of time that is summer	unitless	6.70E-01
Fraction of time that is winter	unitless	3.30E-01
Esitmated Daily Intake from Food Sources	ug/kg bw/day	2.40E+0C
CALCULATED VALUES		
Fraction of time spent outdoors in background-winter	unitless	2.75E-02
Fraction of time spent outdoors in background- summer	unitless	8.38E-02
Fraction of time spent indoors in background - winter	unitless	3.03E-01
Fraction of time spent indoors in background - summer	unitless	5 87E-01
CALCULATED VALUES - (BKG - SITE)		
Fraction of time spent outdoors away from Deloro -winter	unitless	3.44E-03
Fraction of time spent outdoors away from Deloro- summer	unitless	1.04E-02
Fraction of time spent indoors away from Deloro - winter	unitless	3.78E-02
Fraction of time spent indoors away from Deloro - summer	unitless	7.41E-02
Amount of time spent away from Deloro for any given Seaso	hrs/wk	2.11E+01
Amount of time spent in Deloro for any given Season	hrs/wk	1 47E+02
total time		1 68E+02

HUMAN RECEPTOR PARAMETERS

GENDER (combined) — COMBINED

AGE CLASS		INFANT		PRESCHOOL CHILD		CHILD		ADOLESCENT		ADULT	
SCENARIO		plausible max	mean (typical)	plausible max	mean (typical)	plausible max	mean (typical)	plausible max	mean (typical)	plausible max	mean (typical)
EXPOSURE PARAMETERS	UNITS										
Body weight	kg	8.20E+00	8.20E+00	1.65E+01	1.65E+01	3.29E+01	3.29E+01	5.97E+01	5.97E+01	7.07E+01	7.07E+01
Area of Exposed Skin - summer days	m^2	2.64E-01	2.09E-01	4.63E-01	3.56E-01	7.84E-01	5.89E-01	1.16E+00	9.25E-01	1.22E+00	1.01E+00
Area of Exposed Skin - winter days	m^2	1.07E-01	8.51E-02	2.00E-01	1.53E-01	2.37E-01	1.78E-01	2.70E-01	2.15E-01	2.60E-01	2.15E-01
Whole Body Surface Area	m^2	4.57E-01	3.62E-01	7.99E-01	8.13E-01	1.35E+00	1.01E+00	1.94E+00	1.55E+00	2.13E+00	1.76E+00
Soil Adherence Factor	g/m^2/d	1.00E+01	5.85E+00	1.00E+01	5.85E+00	1.00E+01	5.85E+00	1.00E+01	5.85E+00	1.00E+01	5.85E+00
Total Amount of Soil & Dust Ingested	g/day	2.00E-01	8.00E-02	2.00E-01	8.00E-02	2.00E-01	8.00E-02	1.00E-01	2.00E-02	1.00E-01	2.00E-02
Percentage of ingestion exposure via indoor dust	unitless	5.50E-01	5.50E-01	5.50E-01	5.50E-01	5.50E-01	5.50E-01	5.50E-01	5.50E-01	5.50E-01	5.50E-01
Percentage of ingestion exposure via outdoor soil	unitless	4.50E-01	4.50E-01	4.50E-01	4.50E-01	4.50E-01	4.50E-01	4.50E-01	4.50E-01	4.50E-01	4.50E-01
Amount of Air Inhaled	m^3/day	3.20E+00	3.10E+00	1.41E+01	9.30E+00	2.03E+01	1.45E+01	2.31E+01	1.58E+01	2.29E+01	1.58E+01
Amount of time spent outdoors in Deloro - winter	hrs/wk	12.25	12.25	12.25	12.25	12.25	9.30	12.25	8.17	12.25	8.17
Amount of time spent outdoors in Deloro - summer	hrs/wk	18.38	18.38	26.33	18.38	26.33	14.00	26.33	12.16	18.38	12.16
Amount of time spent indoors in Deloro - winter	hrs/wk	134.75	134.75	134.75	134.75	134.75	103.00	134.75	89.80	134.75	89.80
Amount of time spent indoors in Deloro - summer	hrs/wk	128.63	128.63	120.66	128.63	120.66	98.00	120.66	85.75	128.63	85.75
Amount of time on site (trespasser) - winter	hrs/wk	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Amount of time on site (trespasser) - summer	hrs/wk	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Amount of time spent in Deloro for any given Season	hrs/wk	147.01	147.01	147.00	147.01	147.00	112.15	147.00	97.95	147.00	97.95
Fraction of time that is summer	unitless	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01
Fraction of time that is winter	unitless	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
Fraction of Produce from Home Garden	unitless	0.00E+00	0.00E+00	7.40E-02	7.40E-02	7.40E-02	7.40E-02	7.40E-02	7.40E-02	7.40E-02	7.40E-02
Fraction of Fruit and Juices consumed	unitless	0.00E+00	0.00E+00	2.70E-02	2.70E-02	2.70E-02	2.70E-02	2.70E-02	2.70E-02	2.70E-02	2.70E-02
Amount of Water Consumed	L/day	6.77E-01	3.00E-01	1.35E+00	6.00E-01	1.56E+00	8.00E-01	2.13E+00	1.00E+00	3.01E+00	1.50E+00
Amount of Fruit and Juices consumed	g/day	3.18E+02	1.36E+02	5.79E+02	2.34E+02	6.99E+02	2.68E+02	6.88E+02	2.58E+02	8.18E+02	2.45E+02
Amount of Root Vegetables Consumed	g/day	1.92E+02	8.30E+01	2.72E+02	1.05E+02	4.25E+02	1.61E+02	5.59E+02	2.27E+02	4.68E+02	1.88E+02
Amount of Other Vegetables Consumed	g/day	1.81E+02	7.20E+01	1.95E+02	6.70E+01	2.88E+02	9.80E+01	3.54E+02	1.20E+02	3.70E+02	1.37E+02
Estimated Urinary Output	l/day	2.40E-01	2.40E-01	3.55E-01	3.55E-01	7.00E-01	7.00E-01	1.40E+00	1.40E+00	1.40E+00	1.40E+00
Fraction of Inorganic Arsenic excreted daily	unitless	6.00E-01	5.00E-01	6.00E-01	5.00E-01	6.00E-01	5.00E-01	6.00E-01	5.00E-01	6.00E-01	5.00E-01
Age class duration	yr	5.00E-01	5.00E-01	4.50E+00	4.50E+00	7.00E+00	7.00E+00	8.00E+00	8.00E+00	5.00E+01	5.00E+01
Entire Lifespan	yr	7.00E+01	7.00E+01	7.00E+01	7.00E+01	7.00E+01	7.00E+01	7.00E+01	7.00E+01	7.00E+01	7.00E+01
Carcinogenic Amortization Factor	unitless	7.14E-03	7.14E-03	6.43E-02	6.43E-02	1.00E-01	1.00E-01	1.14E-01	1.14E-01	7.14E-01	7.14E-01
CALCULATED VALUES											
Time spent outdoors in the village - winter	unitless	2.01E-02	2.01E-02	2.01E-02	2.01E-02	2.01E-02	1.43E-02	2.01E-02	1.21E-02	2.01E-02	1.21E-02
Time spent outdoors in the village - summer	unitless	8.53E-02	8.53E-02	9.70E-02	8.53E-02	9.70E-02	4.79E-02	9.70E-02	4.06E-02	6.53E-02	4.06E-02
Time spent indoors at home - winter	unitless	2.65E-01	2.65E-01	2.65E-01	2.65E-01	2.65E-01	2.02E-01	2.65E-01	1.78E-01	2.65E-01	1.76E-01
Time spent indoors at home - summer	unitless	5.13E-01	5.13E-01	4.81E-01	5.13E-01	4.81E-01	3.91E-01	4.81E-01	3.42E-01	5.13E-01	3.42E-01
Amount of time on site (trespasser) - winter	unitless	3.93E-03	3.93E-03	3.93E-03	3.93E-03	3.93E-03	3.93E-03	3.93E-03	3.93E-03	3.93E-03	3.93E-03
Amount of time on site (trespasser) - summer	unitless	7.98E-03	7.98E-03	7.98E-03	7.98E-03	7.98E-03	7.98E-03	7.98E-03	7.98E-03	7.98E-03	7.98E-03
BACKGROUND EXPOSRUE PARAMETERS											
Amount of time spent outdoors - winter	hrs/wk	1.40E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01	1.40E+01
Amount of time spent outdoors - summer	hrs/wk	2.10E+01	2.10E+01	3.01E+01	2.10E+01	3.01E+01	2.08E+01	3.01E+01	2.08E+01	2.08E+01	2.08E+01
Amount of time spent indoors - winter	hrs/wk	1.54E+02	1.54E+02	1.54E+02	1.54E+02	1.54E+02	1.54E+02	1.54E+02	1.54E+02	1.54E+02	1.54E+02
Amount of time spent indoors - summer	hrs/wk	1.47E+02	1.47E+02	1.38E+02	1.47E+02	1.38E+02	1.46E+02	1.38E+02	1.47E+02	1.47E+02	1.47E+02
Total amount of time accumulated in one week	hrs/wk	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02
Fraction of time that is summer	unitless	6.70E-01	8.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01	6.70E-01
Fraction of time that is winter	unitless	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01	3.30E-01
Estimated Daily Intake from Food Sources	ug/kg bw/day	2.40E+00	5.80E-01	2.00E+00	2.90E-01	1.90E+00	1.45E-01	1.20E+00	1.70E-01	6.00E-01	1.45E-01
CALCULATED VALUES											
Fraction of time spent outdoors in background - winter	unitless	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02	2.75E-02
Fraction of time spent outdoors in background - summer	unitless	8.38E-02	8.38E-02	1.20E-01	8.38E-02	1.20E-01	8.30E-02	1.20E-01	8.30E-02	8.30E-02	8.30E-02
Fraction of time spent indoors in background - winter	unitless	3.03E-01	3.03E-01	3.03E-01	3.03E-01	3.03E-01	3.03E-01	3.03E-01	3.03E-01	3.03E-01	3.03E-01
Fraction of time spent indoors in background - summer	unitless	5.87E-01	5.87E-01	5.50E-01	5.87E-01	5.50E-01	5.83E-01	5.50E-01	5.87E-01	5.87E-01	5.87E-01
CALCULATED VALUES - (BKG - SITE)											
Fraction of time spent outdoors away from Deloro - winter	unitless	3.44E-03	3.44E-03	3.44E-03	3.44E-03	3.44E-03	9.23E-03	3.44E-03	1.15E-02	3.44E-03	1.15E-02
Fraction of time spent outdoors away from Deloro - summer	unitless	1.04E-02	1.04E-02	1.50E-02	1.04E-02	1.50E-02	2.71E-02	1.50E-02	3.44E-02	9.67E-03	3.44E-02
Fraction of time spent indoors away from Deloro - winter	unitless	3.78E-02	3.78E-02	3.78E-02	3.78E-02	3.78E-02	1.00E-01	3.78E-02	1.26E-01	3.78E-02	1.26E-01
Fraction of time spent indoors away from Deloro - summer	unitless	7.41E-02	7.41E-02	6.68E-02	7.41E-02	6.68E-02	1.93E-01	6.68E-02	2.45E-01	7.41E-02	2.45E-01
Amount of time spent away from Deloro for any given Season	hrs/wk	2.11E+01	2.11E+01	2.10E+01	2.11E+01	2.10E+01	5.53E+01	2.10E+01	7.01E+01	2.10E+01	7.01E+01
Amount of time spent in Deloro for any given Season	hrs/wk	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.47E+02	1.12E+02	1.47E+02	9.79E+01	1.47E+02	9.79E+01
Total time		1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02	1.67E+02	1.68E+02	1.68E+02	1.68E+02	1.68E+02

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

MERCURY										
LOCATION	BACKGROUND			Village			On-site			
SCENARIO	plausible max	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	
SOURCE	linked	linked	linked	linked	linked	linked	linked	linked	linked	
MEDIA										
SOIL (ug/g)	1 70E+01	1 40E+01	1 57E+01	3 08E+02	1 11E+02	4 72E+02	1 23E+01	3 28E+00		
OUTDOOR AIR (ug/m^3) - winter	7 00E-03	1 00E-03	3 96E-03	2 03E-04	1 70E-04	2 71E-04	2 46E-07	3 28E-07		
OUTDOOR AIR (ug/m^3) - summer	7 00E-03	1 00E-03	2 33E-03	2 03E-04	1 70E-04	1 06E-04	2 46E-07	3 28E-07		
INDOOR AIR (ug/m^3) -winter	5 25E-03	7 50E-04	2 97E-03	1 52E-04	1 28E-04	2 03E-04				using Roberts 1974, 75% of outdoor air is indoor
INDOOR AIR (ug/m^3) -summer	5 25E-03	7 50E-04	1 75E-03	1 52E-04	1 28E-04	7 84E-05				
INDOOR DUST (ug/g) - winter	6 63E-01	5 46E-01	8 14E-01	1 20E+01	4 34E+00	1 84E+01				using Hwang and Calabrese approximately 39% of soil conc Is dust conc
INDOOR DUST (ug/g) -summer	6 63E+00	5 46E+00	6 14E+00	1 20E+02	4 34E+01	1 84E+02				Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
ROOT VEGETABLES (ug/g wet weight)	6 80E-02	5 60E-02	6 29E-02	4 00E-01	1 45E-01	6 14E-01				Background HGP based on Baas, than converted to fresh weight according to Mercury report
OTHER VEGETABLES (ug/g wet weight)	2 72E-02	2 24E-02	2 52E-02	1 11E+00	4 00E-01	1 70E+00				used lettuce concentrations
FRUIT (ug/g wet weight)	1 07E-01	8 79E-02	9 88E-02	4 35E+00	1 57E+00	6 66E+00				assuming same as onsite lettue dry weight and adjusting by everage fruit moisture content
WELL WATER (ug/L)				5 10E+00	5 10E+00	2 50E+00				
MUNICIPAL WATER SUPPLY (ug/L)				5 10E+00	5 10E+00	5 10E+00				
BACKGROUND WATER SUPPLY (ug/L)	1 00E+00	5 00E-01	7 79E-01							

CHEMCAL TOXCITY DATA	MERCURY		
	plausible max	mean (typical)	stochastic
Inhalation Bioavailability	0 37	0 37	0 34
Oral Bioavailability of Food	0 9	0 9	0 9
Oral Bioavailability from Water	0 95	0 95	0 95
Oral Bioavailability from Soil	0 4	0 4	0 14
Oral Bioavailability from Dust	0 19	0 19	0 19
Dermal Bioavailability	0 0006	0 0006	0 0019
Inhalation Study Bioavailability	0 37	0 37	0 34
Oral Study Bioavailability	0 4	0 4	0 95
TOXICITY DATA	TYPE	VALUE	
Carcinogen (yes/no)	no		
Inhalation Exposure limit (ug/kg bw 1d)	RfD	1 71E-02	
[illegible] kg bw d	RfD	0 06	

Winter Covering Factor [illegible]	1 00E 01
Acceptable Risk Level	1 [illegible]E 06
Chemical Specific soil vegetation Transfer Factor	0 04
Site and Chemical Specific Root BTF - Max	0 013
Site and Chemical Specific Root BTF - Mean	0 013
Site and Chemical Specific Root BTF - Range	0 013
Site and Chemical Specific Vegetation BTF - Max	0 09
Site and Chemical Specific Vegetation BTF - Mean	0 09
Site and Chemical Specific Vegetation BTF - Range	0 09
Dry to wet weight conversion factor for root type veg	0 1
Dry to wet weight conversion factor for other veg	0 04
Dry to wet weight conversion factor for fruits	0 157

Fraction of arsenic that is inorganic in vegetation 0 1

I	J	K	L	M	N	O	P	Q

On-site	
nean (typical) linked	stochastic linked
3 28E+00	
3 28E-07	
3 28E-07	

using Roberts 1974; 75% of outdoor eir is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Have applied e 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
espasser Scenario - Only						
loro Exposure (µg/kg bw/d)		**AP**	**ADULT**		**COMPOSITE**	
erministic Scenario			**max**	**mean**	**max**	**mean**
spasser-inhalation		**x**	.51E-10	3.23E-10		
spasser-oral		**x**	.20E-04	1.69E-05		
spasser-dermal		**x**	.03E-05	1.33E-06		
alation Pathway (Site)			.51E-10	3.23E-10		
estion/Dermal Pathways (Site)			.31E-04	1.82E-05		
al Site Exposure (µg/kg bw/day)			.31E-04	1.82E-05		
timated Exposure Ratio (ER)			.61E-03	7.58E-04		

Supplementary trespasser scenario

	C–D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2	***Trespasser Scenario - Only***		***MERCURY***											
3			**COMBINED RECEPTOR**											
4	**Deloro Exposure (µg/kg bw/d)**	**AP**	**INFANT**		**PRESCHOOL CHILD**		**CHILD**		**ADOLESCENT**		**ADULT**		**COMPOSITE**	
5	**Deterministic Scenario**		**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
6	Trespasser-inhalation	x	4.23E-10	5.46E-10	9.23E-10	8.14E-10	6.68E-10	6.37E-10	4.19E-10	3.82E-10	3.51E-10	3.23E-10		
7	Trespasser-oral	x	3.80E-03	4.05E-04	1.39E-03	2.01E-04	6.99E-04	1.29E-04	1.93E-04	2.00E-05	2.20E-04	1.69E-05		
8	Trespasser-dermal	x	1.93E-05	2.39E-06	1.69E-05	2.02E-06	1.42E-05	1.67E-06	1.16E-05	1.44E-06	1.03E-05	1.33E-06		
9	**Inhalation Pathway (Site)**		4.23E-10	5.46E-10	9.23E-10	8.14E-10	6.68E-10	6.37E-10	4.19E-10	3.82E-10	3.51E-10	3.23E-10		
10	**Ingestion/Dermal Pathways (Site)**		3.82E-03	4.08E-04	1.41E-03	2.03E-04	7.13E-04	1.30E-04	2.04E-04	2.14E-05	2.31E-04	1.82E-05		
11	**Total Site Exposure (µg/kg bw/day)**		3.82E-03	4.08E-04	1.41E-03	2.03E-04	7.13E-04	1.30E-04	2.04E-04	2.14E-05	2.31E-04	1.82E-05		
12	**Estimated Exposure Ratio (ER)**		1.59E-01	1.70E-02	5.88E-02	8.48E-03	2.97E-02	5.43E-03	8.51E-03	8.92E-04	5.61E-03	7.58E-04		

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

COPPER										
LOCATION	*BACKGROUND*			*Village*			*On-site*			
SCENARIO	plausible max	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	plausible max	mean (typical)	stochastic	
SOURCE	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	
MEDIA										
[illegible]	1 70E+01	1 40E+01	1 57E+01	3 08E+02	1 11E+02	4 72E+02	7 94E+02	2 80E+02		
[illegible] AIR [illegible] winter	7 00E-03	1 00E-03	3 96E-03	2 03E-04	1 70E-04	2 71E-04	1 59E 05	2 80E 05		
[illegible] AIR [illegible] summer	7 00E-03	1 00E-03	2 33E-03	2 03E-04	1 70E-04	1 06E-04	1 59E-05	2 80E 05		
INDOOR AIR (ug/m^3) winter	5 25E-03	7 50E-04	2 97E-03	1 62E-04	1 28E-04	2 03E-04				using Roberts 1974, 75% of outdoor air is indoor
INDOOR AIR (ug/m^3) summer	5 25E-03	7 50E-04	1 75E-03	1 52E-04	1 28E-04	7 94E-05				
INDOOR DUST (ug/g) - winter	6 63E-01	5 46E-01	6 14E-01	1 20E+01	4 34E+00	1 84E+01				using Hwang and Calabrese approximately 39% of soil conc Is dust conc
INDOOR DUST (ug/g) - summer	6 63E+00	5 46E+00	6 14E+00	1 20E+02	4 34E+01	1 84E+02				Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
ROOT VEGETABLES (ug/g wet weight)	8 80E-02	5 60E-02	6 29E-02	4 00E-01	1 45E-01	6 14E-01				Background HGP based on *Baes* then converted to fresh weight according to Mercury report
OTHER VEGETABLES (ug/g wet weight)	2 72E-02	2 24E-02	2 52E-02	1 11E+00	4 00E-01	1 70E+00				used lettuce concentrations
FRUIT (ug/g wet weight)	1 07E-01	8 79E-02	9 68E-02	4 35E+00	1 57E+00	6 68E+00				assuming same as onsite lettue dry weight and adjusting by average fruit moisture content
WELL WATER (ug/L)				5 10E+00	5 10E+00	2 50E+00				
MUNICIPAL WATER SUPPLY (ug/L)				5 10E+00	5 10E+00	5 10E+00				
BACKGROUND WATER SUPPLY (ug/L)	1 00E+00	5 00E-01	7 79E-01							

CHEMCAL TOXCITY OATA	COPPER		
	plausible max	mean (typical)	stochastic
[illegible]	[illegible]	[illegible]	0 34
Oral Bioavailability of Food	0 9	0 9	0 9
Oral Bioavailability from Water	0 95	0 95	0 95
[illegible]	[illegible]	[illegible]	0 14
Oral Bioavailability from Dust	0 19	0 19	0 19
[illegible]			0 0019
[illegible]	[illegible]	[illegible]	0 34
[illegible]	[illegible]		0 95
TOXICITY DATA	TYPE	VALUE	
Carcinogen (yes no)	no		
[illegible]	RfD	1 56E+00	
[illegible]	RfD	7 42	

[illegible]	
[illegible]	
Chemical Specific soil vegetation Transfer Factor	0 04
Site and Chemical Specific Root BTF Max	0 013
Site and Chemical Specific Root BTF Mean	0 013
Site and Chemical Specific Root BTF Range	0 013
Site and Chemical Specific Vegetation BTF Max	0 09
Site and Chemical Specific Vegetation BTF Mean	0 09
Site and Chemical Specific Vegetation BTF Range	0 09
Dry to wet weight conversion factor for root type veg	0 1
Dry to wet weight conversion factor for other veg	0 04
Dry to wet weight conversion factor for fruits	[illegible]

Fraction of [illegible] that is inorganic in vegetation

	I	J	K	L	M	N	O	P	Q

On-site		
ax.	mean (typical)	stochastic
	linked	linked
	2 80E+02	
	2 80E-05	
	2 80E-05	

using Roberts 1974; 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
spasser Scenario - Only						
oro Exposure (µg/kg bw/d)		AP	ADULT		COMPOSITE	
			max	mean	max	mean
rministic Scenario						
passer-inhalation		x	.67E-08	3.42E-08		
passer-oral		x	.79E-02	1.99E-03		
passer-dermal		x	.65E-02	6.23E-03		
lation Pathway (Site)			.67E-08	3.42E-08		
stion/Dermal Pathways (Site)			.44E-02	8.22E-03		
l Site Exposure (µg/kg bw/day)			.44E-02	8.22E-03		
timated Exposure Ratio (ER)			.10E-02	1.41E-03		

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Trespasser Scenario - Only			***COPPER***											
			COMBINED RECEPTOR											
Deloro Exposure (µg/kg bw/d)		**AP**	**INFANT**		**PRESCHOOL CHILD**		**CHILD**		**ADOLESCENT**		**ADULT**		**COMPOSITE**	
Deterministic Scenario			**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
Trespasser-inhalation		x	4.42E-08	5.79E-08	9.66E-08	8.63E-08	6.98E-08	6.75E-08	4.38E-08	4.05E-08	3.67E-08	3.42E-08		
Trespasser-oral		x	4.82E-01	4.78E-02	1.77E-01	2.37E-02	8.86E-02	1.52E-02	2.44E-02	2.35E-03	2.79E-02	1.99E-03		
Trespasser-dermal		x	6.86E-02	1.12E-02	5.99E-02	9.48E-03	5.05E-02	7.83E-03	4.10E-02	6.75E-03	3.65E-02	6.23E-03		
Inhalation Pathway (Site)			4.42E-08	5.79E-08	9.66E-08	8.63E-08	6.98E-08	6.75E-08	4.38E-08	4.05E-08	3.67E-08	3.42E-08		
Ingestion/Dermal Pathways (Site)			5.50E-01	5.90E-02	2.37E-01	3.32E-02	1.39E-01	2.30E-02	6.54E-02	9.11E-03	6.44E-02	8.22E-03		
Total Site Exposure (µg/kg bw/day)			5.50E-01	5.90E-02	2.37E-01	3.32E-02	1.39E-01	2.30E-02	6.54E-02	9.11E-03	6.44E-02	8.22E-03		
Estimated Exposure Ratio (ER)			9.44E-02	1.01E-02	4.06E-02	5.70E-03	2.39E-02	3.94E-03	1.12E-02	1.56E-03	1.10E-02	1.41E-03		

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

CADMIUM									
LOCATION	BACKGROUND			Village			On-site		
SCENARIO	plausible max	mean (typical)	stochastic	plausible max	mean (typical)	stochastic	plausible max	mean (typical)	stochastic
SOURCE	linked	linked	linked	linked	linked	linked	linked	linked	linked
MEDIA									
[illegible]	1.70E+01	1.40E+01	1.57E+01	3.08E+02	1.11E+02	4.72E+02	[illegible]	[illegible]	
[illegible]	7.00E-03	1.00E-03	3.95E-03	2.03E-04	1.70E-04	2.71E-04	[illegible]	[illegible]	
[illegible]	7.00E-03	1.00E-03	2.33E-03	2.03E-04	1.70E-04	1.06E-04	[illegible]	[illegible]	
INDOOR AIR (ug/m^3) winter	5.25E-03	7.50E-04	2.97E-03	1.52E-04	1.28E-04	2.03E-04			
INDOOR AIR (ug/m^3) summer	5.25E-03	7.50E-04	1.75E-03	1.52E-04	1.28E-04	7.94E-05			
INDOOR DUST (ug/g) winter	6.63E-01	5.46E-01	6.14E-01	1.20E+01	4.34E+00	1.84E+01			
INDOOR DUST (ug/g) summer	6.63E+00	5.46E+00	6.14E+00	1.20E+02	4.34E+01	1.84E+02			
ROOT VEGETABLES (ug/g wet weight)	6.80E-02	5.60E-02	6.29E-02	4.00E-01	1.45E-01	6.14E-01			
OTHER VEGETABLES (ug/g wet weight)	2.72E-02	2.24E-02	2.52E-02	1.11E+00	4.00E-01	1.70E+00			
FRUIT (ug/g wet weight)	1.07E-01	8.79E-02	9.88E-02	4.35E+00	1.57E+00	6.68E+00			
WELL WATER (ug/L)				5.10E+00	5.10E+00	2.50E+00			
MUNICIPAL WATER SUPPLY (ug/L)				5.10E+00	5.10E+00	5.10E+00			
BACKGROUND WATER SUPPLY (ug/L)	1.00E+00	5.00E-01	7.79E-01						

using Roberts 1974 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. is dust conc

Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil

Background HGP based on Bass then converted to fresh weight according to Mercury report

used lettuce concentrations

assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

CHEMCAL TOXCITY DATA	CADMIUM	as a non-carcinogen	
	plausible max	mean (typical)	stochastic
[illegible]	[illegible]	[illegible]	0.14
Bioavailability of Food	[illegible]	[illegible]	[illegible]
Bioavailability from Water	0.95	0.95	0.95
[illegible]	[illegible]	[illegible]	0.14
Bioavailability from Dust	[illegible]	0.19	0.19
[illegible]			0.0019
[illegible]			0.34
[illegible]			0.95
TOXICITY DATA	TYPE	VALUE	
[illegible]			
[illegible]	[illegible]	[illegible]	
[illegible]	[illegible]	[illegible]	

[illegible] Transfer Factor	[illegible]
[illegible] (BTF) Max	[illegible]
[illegible] (BTF) Mean	[illegible]
[illegible] (BTF) Range	[illegible]
[illegible] vegetation (BTF) Max	[illegible]
[illegible] vegetation (BTF) Mean	[illegible]
[illegible] vegetation (BTF) Range	[illegible]
[illegible] wet weight [illegible] factor for root type veg	[illegible]
[illegible] wet weight [illegible] factor for other veg	[illegible]
[illegible]	[illegible]

[illegible] vegetation

I	J	K	L	M	N	O	P	Q

On-site	
mean (typical)	stochastic
linked	*linked*
1 75E+01	
1 75E-06	
1 75E-06	

using Roberts 1974; 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
spasser Scenario - Only						
oro Exposure (µg/kg bw/d)		**AP**	**ADULT**		**COMPOSITE**	
rministic Scenario			**max**	**mean**	**max**	**mean**
passer-inhalation		x	1.64E-09	8.14E-10		
passer-oral		x	6.78E-04	1.83E-05		
passer-dermal		x	1.35E-03	8.86E-05		
lation Pathway (Site)			1.64E-09	8.14E-10		
stion/Dermal Pathways (Site)			2.03E-03	1.07E-04		
l Site Exposure (µg/kg bw/day)			2.03E-03	1.07E-04		
timated Exposure Ratio (ER)			1.30E-01	6.85E-03		

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2	***Trespasser Scenario - Only***			***CADMIUM*** *- es a non-carcinogen*											
3				**COMBINED RECEPTOR**											
4	**Deloro Expoeure (µg/kg bw/d)**		**AP**	**INFANT**		**PRESCHOOL CHILO**		**CHILD**		**ADOLESCENT**		**ADULT**		**COMPOSITE**	
5	**Deterministic Scenario**			**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
6	Trespasser-inhalation		x	1.98E-09	1.38E-09	4.33E-09	2.05E-09	3.13E-09	1.61E-09	1.96E-09	9.64E-10	1.64E-09	8.14E-10		
7	Trespasser-oral		x	1.17E-02	4.40E-04	4.29E-03	2.19E-04	2.15E-03	1.40E-04	5.92E-04	2.17E-05	6.78E-04	1.83E-05		
8	Trespasser-dermal		x	2.54E-03	1.59E-04	2.22E-03	1.35E-04	1.87E-03	1.11E-04	1.52E-03	9.60E-05	1.35E-03	8.86E-05		
9	**Inhalation Pathway (Site)**			1.98E-09	1.38E-09	4.33E-09	2.05E-09	3.13E-09	1.61E-09	1.96E-09	9.64E-10	1.64E-09	8.14E-10		
10	**Ingestion/Dermal Pathways (Site)**			1.42E-02	6.00E-04	6.51E-03	3.54E-04	4.02E-03	2.51E-04	2.11E-03	1.18E-04	2.03E-03	1.07E-04		
11	**Total Site Exposure (µg/kg bw/day)**			1.42E-02	6.00E-04	6.51E-03	3.54E-04	4.02E-03	2.51E-04	2.11E-03	1.18E-04	2.03E-03	1.07E-04		
12	**Estimated Exposure Ratio (ER)**			9.12E-01	3.84E-02	4.17E-01	2.27E-02	2.58E-01	1.61E-02	1.35E-01	7.54E-03	1.30E-01	6.85E-03		

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

BERYLLIUM										
LOCATION	*BACKGROUND*			*Village*			*On-site*			
SCENARIO	plausible max	mean (typical)	stochastic	plausible max	mean (typical)	stochastic	plausible max	mean (typical)	stochastic	
SOURCE	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	
MEDIA										
SOIL (ug/g)	1.70E+01	1.40E+01	1.57E+01	3.08E+02	1.11E+02	4.72E+02	1.15E+00	4.63E-01		
OUTDOOR AIR (ug/m^3) - winter	7.00E-03	1.00E-03	3.96E-03	2.03E-04	1.70E-04	2.71E-04	2.30E-08	4.63E-08		
OUTDOOR AIR (ug/m^3) - summer	7.00E-03	1.00E-03	2.33E-03	2.03E-04	1.70E-04	1.06E-04	2.30E-08	4.63E-08		
INDOOR AIR (ug/m^3) -winter	5.25E-03	7.50E-04	2.97E-03	1.52E-04	1.28E-04	2.03E-04				using Roberts 1974, 75% of outdoor air is indoor
INDOOR AIR (ug/m^3) -summer	5.25E-03	7.50E-04	1.75E-03	1.52E-04	1.28E-04	7.94E-05				
INDOOR DUST (ug/g) - winter	6.63E-01	5.46E-01	8.14E-01	1.20E+01	4.34E+00	1.84E+01				using Hwang and Calabrese approximately 39% of soil conc. Is dust conc
INDOOR DUST (ug/g) -summer	6.83E+00	5.46E+00	6.14E+00	1.20E+02	4.34E+01	1.84E+02				Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
ROOT VEGETABLES (ug/g wet weight)	6.80E-02	5.60E-02	6.29E-02	4.00E-01	1.45E-01	6.14E-01				Background HGP based on Baes then converted to fresh weight according to Mercury report
OTHER VEGETABLES (ug/g wet weight)	2.72E-02	2.24E-02	2.52E-02	1.11E+00	4.00E-01	1.70E+00				used lettuce concentrations
FRUIT (ug/g wet weight)	1.07E-01	8.79E-02	9.88E-02	4.35E+00	1.57E+00	6.68E+00				assuming same as onsite lettue dry weight and adjusting by average fruit moisture content
WELL WATER (ug/L)				5.10E+00	5.10E+00	2.50E+00				
MUNICIPAL WATER SUPPLY (ug/L)				5.10E+00	5.10E+00	5.10E+00				
BACKGROUND WATER SUPPLY (ug/L)	1.00E+00	5.00E-01	7.79E-01							

CHEMCAL TOXCITY DATA	BERYLLIUM	- as a non-carcinogen	
	plausible max	mean (typical)	stochastic
Inhalation Bioavailability	*0.136*	*0.136*	0.34
Oral Bioavailability of Food	0.9	0.9	0.9
Oral Bioavailability from Water	0.95	0.95	0.95
Oral Bioavailability from Soil	0.01	0.01	0.14
Oral Bioavailability from Dust	0.19	0.19	0.19
Dermal Bioavailability	0.0006	0.0006	0.0019
Inhalation Study Bioavailability	0.136	0.136	0.34
Oral Study Bioavailability	[illegible]	0.01	0.95
TOXICITY DATA	**TYPE**	**VALUE**	
Carcinogen (yes/no)	no		
Inhalation Exposure limit (ug/kg bw/day)	RfD	1.14E-04	
Oral [illegible] (ug/kg bw/day)	RfD	1.00E+00	

Winter Covering Factor (units)	[illegible]
Acceptable Risk Level	[illegible]0E-06
Chemical Specific soil-vegetation Transfer Factor	0.04
Site and Chemical Specific Root BTF - Max	0.013
Site and Chemical Specific Root BTF - Mean	0.013
Site and Chemical Specific Root BTF - Range	0.013
Site and Chemical Specific Vegetation BTF - Max	0.09
Site and Chemical Specific Vegetation BTF - Mean	0.09
Site and Chemical Specific Vegetation BTF - Range	0.09
Dry to wet weight conversion factor for root type veg	0.1
Dry to wet weight conversion factor for other veg	0.04
Dry to wet weight conversion factor for fruits	0.157

Fraction of arsenic that is inorganic in vegetation 0.1

	I	J	K	L	M	N	O	P	Q

	On-site	
ax.	mean (typical)	stochastic
	linked	*linked*
0	4 63E-01	
8	4 63E-08	
8	4 63E-08	

using Roberts 1974; 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
spasser Scenario - Only		***I***				
pro Exposure (µg/kg bw/d)		**AP**	**ADULT**		**COMPOSITE**	
rministic Scenario			**max**	**mean**	**max**	**mean**
passer-inhalation		**x**	1.21E-11	1.67E-11		
passer-oral		**x**	5.15E-07	5.95E-08		
passer-dermal		**x**	9.62E-07	1.87E-07		
lation Pathway (Site)			1.21E-11	1.67E-11		
stion/Dermal Pathways (Site)			1.48E-06	2.47E-07		
l Site Exposure (µg/kg bw/day)			1.48E-06	2.47E-07		
imated Exposure Ratio (ER)			1.48E-04	2.58E-05		

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Trespasser Scenario - Only			***BERYLLIUM*** ***- as a non-carcinogenic***											
			COMBINED RECEPTOR											
Deloro Exposure (µg/kg bw/d)		**AP**	**INFANT**		**PRESCHDDL CHILD**		**CHILD**		**ADDLESCENT**		**ADULT**		**COMPOSITE**	
Deterministic Scenario			**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
Trespasser-inhalation		x	1 45E-11	2.83E-11	3.17E-11	4.22E-11	2 29E-11	3.30E-11	1.44E-11	1.98E-11	1 21E-11	1.67E-11		
Trespasser-oral		x	8.88E-06	1.43E-06	3.26E-06	7 10E-07	1.63E-06	4 53E-07	4.50E-07	7.04E-08	5.15E-07	5.95E-08		
Trespasser-dermal		x	1.81E-06	3 37E-07	1.58E-06	2.85E-07	1.33E-06	2.35E-07	1.08E-06	2.03E-07	9.62E-07	1.87E-07		
Inhalation Pathway (Site)			1 45E-11	2.83E-11	3.17E-11	4.22E-11	2.29E-11	3.30E-11	1.44E-11	1.98E-11	1.21E-11	1.67E-11		
Ingestion/Dermal Pathways (Site)			1 07E-05	1.77E-06	4 84E-06	9.95E-07	2.97E-06	6.89E-07	1.53E-06	2.73E-07	1.48E-06	2 47E-07		
Total Site Exposure (µg/kg bw/day)			1 07E-05	1.77E-06	4.84E-06	9 95E-07	2.97E-06	6.89E-07	1.53E-06	2.73E-07	1.48E-06	2.47E-07		
Estimated Exposure Ratio (ER)			1.07E-03	1.78E-04	4.86E-04	1.02E-04	2.98E-04	7.10E-05	1.54E-04	2 86E-05	1.48E-04	2.58E-05		

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

CADMIUM										
LOCATION	*BACKGROUND*			*Village*			*On-site*			
SCENARIO	plausible max	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	
SOURCE	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	
MEDIA										
[illegible]	1 70E+01	1 40E+01	1 57E+01	3 08E+02	1 11E+02	4 72E+02	[illegible]	[illegible]		
[illegible] winter	7 00E-03	1 00E-03	3 96E-03	2 03E-04	1 70E-04	2 71E-04	1 94E 06	1 75E-06		
[illegible] summer	[illegible] 00E-03	1 00E-03	2 33E-03	2 03E-04	1 70E-04	1 06E-04	1 94E 06	1 75E 06		
INDOOR AIR (ug/m^3) winter	5 25E-03	7 50E-04	2 97E-03	1 52E-04	1 28E-04	2 03E-04				using Roberts 1974, 75% of outdoor air is indoor
INDOOR AIR (ug/m^3) summer	5 25E-03	7 50E-04	1 75E-03	1 52E-04	1 26E-04	7 94E-05				
INDOOR DUST (ug/g) - winter	6 63E-01	5 46E-01	6 14E-01	1 20E+01	4 34E+00	1 84E+01				using Hwang and Calabrese approximately 39% of soil conc. Is dust conc
INDOOR DUST (ug/g) -summer	6 63E+00	5 46E+00	6 14E+00	1 20E+02	4 34E+01	1 84E+02				Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
ROOT VEGETABLES (ug/g wet weight)	6 60E-02	5 60E-02	6 29E-02	4 00E-01	1 45E-01	6 14E-01				Background HGP based on Baes, then converted to fresh weight according to Mercury report
OTHER VEGETABLES (ug/g wet weight)	2 72E-02	2 24E-02	2 52E-02	1 11E+00	4 00E-01	1 70E+00				used lettuce concentrations
FRUIT (ug/g wet weight)	1 07E-01	8 79E-02	9 88E-02	4 35E+00	1 57E+00	6 66E+00				assuming same as onsite lattue dry weight and adjusting by average fruit moisture content
WELL WATER (ug/L)				5 10E+00	5 10E+00	2 50E+00				
MUNICIPAL WATER SUPPLY (ug/L)				5 10E+00	5 10E+00	5 10E+00				
BACKGROUND WATER SUPPLY (ug/L)	1 00E+00	5 00E-01	7 79E-01							

CHEMCAL TDXCITY DATA	CADMIUM	- as a carcinogen	
	plausible max	mean (typical)	stochastic
[illegible]	[illegible]	[illegible]	0 34
Oral Bioavailability of Food	0 9	0 9	0 9
Oral Bioavailability from Water	0 95	0 95	0 95
[illegible]	[illegible]	[illegible]	0 14
Oral Bioavailability from Dust	0 19	0 19	0 19
[illegible]	[illegible]	[illegible]	0 0018
[illegible]	[illegible]	[illegible]	0 34
[illegible]	[illegible]	[illegible]	0 95
TOXICITY DATA	TYPE	VALUE	
Carcinogen (yes/no)	yes		
[illegible]	q*	6 30E-03	
[illegible]	q*		

[illegible]	
Chemical Specific soil-vegetation Transfer Factor	0 04
Site and Chemical Specific Root BTF Max	0 013
Site and Chemical Specific Root BTF Mean	0 013
Site and Chemical Specific Root BTF Range	0 013
Site and Chemical Specific Vegetation BTF Max	0 09
Site and Chemical Specific Vegetation BTF Mean	0 09
Site and Chemical Specific Vegetation BTF Range	0 09
Dry to wet weight conversion factor for root type veg	0 1
Dry to wet weight conversion factor for other veg	0 04
Dry to wet weight conversion factor for fruits	0 157
Fraction [illegible] that is inorganic in vegetation	0 1

	I	J	K	L	M	N	O	P	Q

	On-site	
max.	mean (typical)	stochastic
d	linked	linked
-01	1 75E+01	
06	1 75E-06	
06	1 75E-06	

using Roberts 1974; 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Hava applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
spasser Scenario - Only						
ro Exposure (µg/kg bw/d)		**AP**	**ADULT**		**COMPOSITE**	
rministic Scenario			**max**	**mean**	**max**	**mean**
asser-inhalation asser-oral asser-dermal		**x**	1.64E-09	8.14E-10	2.00E-09	9.94E-10
ation Pathway (Site) **stion/Dermal Pathways (Site)**			1.64E-09	8.14E-10	2.00E-09	9.94E-10
Site Exposure (µg/kg bw/day)			1.64E-09	8.14E-10	2.00E-09	9.94E-10
cer Risk Level (CRL)			3.36E-11	1.67E-11	5.74E-11	2.85E-11

C / D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Trespasser Scenario - Only		***CADMIUM*** **- as a carcinogen**											
		COMBINED RECEPTOR											
Deloro Expoeure (µg/kg bw/d)	**AP**	**INFANT**		**PRESCHOOL CHILD**		**CHILD**		**ADOLESCENT**		**ADULT**		**COMPOSITE**	
Deterministic Scenario		**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
Trespesser-inhalation	x	1.98E-09	1.38E-09	4 33E-09	2 05E-09	3.13E-09	1.61E-09	1.96E-09	9.64E-10	1.64E-09	8.14E-10	2 00E-09	9.94E-10
Trespasser-oral													
Trespasser-dermal													
Inhalation Pathway (Site)		1.98E-09	1.38E-09	4 33E-09	2 05E-09	3.13E-09	1.61E-09	1.96E-09	9 64E-10	1.64E-09	8.14E-10	2.00E-09	9 94E-10
Ingestion/Dermal Pathways (Site)													
Total Site Exposure (µg/kg bw/day)		1 98E-09	1 38E-09	4 33E-09	2.05E-09	3.13E-09	1.61E-09	1.96E-09	9 64E-10	1.64E-09	8.14E-10	2.00E-09	9.94E-10
Cancer Risk Level (CRL)		4 06E-13	2.82E-13	7.97E-12	3.78E-12	8 96E-12	4.60E-12	6.43E-12	3.16E-12	3.36E-11	1.67E-11	5.74E-11	2.85E-11

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

BERYLLIUM										
LOCATION	BACKGROUND			Village			On-site			
SCENARIO	plausible max	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	
SOURCE	linked	linked	linked	linked	linked	linked	linked	linked	linked	
MEDIA										
SOIL (ug/g)	1 70E+01	1 40E+01	1 57E+01	3 08E+02	1 11E+02	4 72E+02	1 15E+00	4 63E-01		
OUTDOOR AIR (ug/m^3) - winter	7 00E-03	1 00E-03	3 96E-03	2 03E-04	1 70E-04	2 71E-04	2 30E-08	4 63E 08		
OUTDOOR AIR (ug/m^3) - summer	7 00E-03	1 00E-03	2 33E-03	2 03E-04	1 70E-04	1 06E-04	2 30E-08	4 63E 08		
INDOOR AIR (ug/m^3) -winter	5 25E-03	7 50E-04	2 97E-03	1 52E-04	1 28E-04	2 03E-04				using Roberts 1974, 75% of outdoor air is indoor
INDOOR AIR (ug/m^3) -summer	5 25E-03	7 50E-04	1 75E-03	1 52E-04	1 28E-04	7 84E-05				
INDOOR DUST (ug/g) - winter	6 63E-01	5 46E-01	6 14E-01	1 20E+01	4 34E+00	1 84E+01				using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
INDOOR DUST (ug/g) -summer	6 63E+00	5 46E+00	6 14E+00	1 20E+02	4 34E+01	1 84E+02				Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistent with outdoor soil
ROOT VEGETABLES (ug/g wet weight)	6 80E-02	5 60E-02	6 28E-02	4 00E-01	1 45E-01	6 14E-01				Background HGP based on Baes, then converted to fresh weight according to Mercury report
OTHER VEGETABLES (ug/g wet weight)	2 72E-02	2 24E-02	2 52E-02	1 11E+00	4 00E-01	1 70E+00				used lettuce concentrations
FRUIT (ug/g wet weight)	1 07E-01	8 79E-02	9 88E-02	4 35E+00	1 57E+00	6 68E+00				assuming same as onsite lettue dry weight and adjusting by average fruit moisture content
WELL WATER (ug/L)				5 10E+00	5 10E+00	2 50E+00				
MUNICIPAL WATER SUPPLY (ug/L)				5 10E+00	5 10E+00	5 10E+00				
BACKGROUND WATER SUPPLY (ug/L)	1 00E+00	5 00E-01	7 79E-01							

CHEMCAL TOXCITY DATA	BERYLLIUM	-as a carcinogen	
	plausible max	mean (typical)	stochastic
Inhalation Bioavailability	0 136	0 136	0 34
Oral Bioavailability of Food	0 9	0 9	0 9
Oral Bioavailability from Water	0 95	0 95	0 95
Oral Bioavailability from Soil	[illegible]	[illegible]	0 14
Oral Bioavailability from Dust	0 19	0 19	0 19
Dermal Bioavailability	0 0006	0 0006	0 0019
Inhalation Study Bioavailability	0 136	0 136	0 34
Oral Study Bioavailability	[illegible]	[illegible]	0 95
TOXICITY DATA	TYPE	VALUE	
Carcinogen (yes/no)	yes		
Inhalation Exposure limit (ug/kg bw/day)	q*	8 40E-03	
[illegible] (ug/kg bw/day)	q*	0 0043	

Water [illegible] Factor [illegible] unitless	1 [illegible]
Acceptable Risk Level	[illegible]E-06
Chemical Specific soil-vegetation Transfer Factor	0 04
Site and Chemical Specific Root BTF - Max	0 013
Site and Chemical Specific Root BTF - Mean	0 013
Site and Chemical Specific Root BTF - Range	0 013
Site and Chemical Specific Vegetation BTF - Max	0 09
Site and Chemical Specific Vegetation BTF - Mean	0 09
Site and Chemical Specific Vegetation BTF - Range	0 09
Dry to wet weight conversion factor for root type veg	0 1
Dry to wet weight conversion factor for other veg	0 04
Dry to wet weight conversion factor for fruits	0 157
Fraction of arsenic that is inorganic in vegetation	0 1

I	J	K	L	M	N	O	P	Q

	On-site	
max.	mean (typical)	stochastic
d	*linked*	*linked*
+00	4 63E-01	
-08	4 63E-08	
-08	4 63E-08	

using Roberts 1974; 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
passer Scenario - Only						
ro Exposure (µg/kg bw/d)		AP	ADULT		COMPOSITE	
ministic Scenario			max	mean	max	mean
asser-inhalation		x	1.21E-11	1.67E-11	1.47E-11	2.04E-11
asser-oral		x	5.15E-07	5.95E-08	8.56E-07	1.52E-07
asser-dermal		x	9.62E-07	1.87E-07	1.06E-06	2.01E-07
ation Pathway (Site)			1.21E-11	1.67E-11	1.47E-11	2.04E-11
tion/Dermal Pathways (Site)			1.48E-06	2.47E-07	1.91E-06	3.53E-07
Site Exposure (µg/kg bw/day)			1.48E-06	2.47E-07	1.91E-06	3.53E-07
er Risk Level (CRL)			4.54E-07	7.58E-08	8.23E-07	1.52E-07

C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
Trespasser Scenario - Only			***BERYLLIUM** - as a carcinogen*											
			COMBINED RECEPTOR											
Deloro Exposure (µg/kg bw/d)		**AP**	**INFANT**		**PRESCHOOL CHILD**		**CHILO**		**ADOLESCENT**		**ADULT**		**COMPOSITE**	
Deterministic Scenario			**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**	**max**	**mean**
Trespasser-inhalation		x	1.45E-11	2 83E-11	3.17E-11	4.22E-11	2.29E-11	3.30E-11	1.44E-11	1.98E-11	1 21E-11	1.67E-11	1.47E-11	2 04E-11
Trespasser-oral		x	8.88E-06	1.43E-06	3 26E-06	7.10E-07	1.63E-06	4 53E-07	4.50E-07	7.04E-08	5.15E-07	5.95E-08	8.56E-07	1.52E-07
Trespasser-dermal		x	1.81E-06	3.37E-07	1.58E-06	2.85E-07	1.33E-06	2 35E-07	1.08E-06	2.03E-07	3.62E-07	1.87E-07	1.06E-06	2.01E-07
Inhalation Pathway (Site)			1.45E-11	2 83E-11	3.17E-11	4 22E-11	2 29E-11	3.30E-11	1.44E-11	1.98E-11	1.21E-11	1.67E-11	1 47E-11	2.04E-11
Ingestion/Dermal Pathways (Site)			1.07E-05	1.77E-06	4 84E-06	9.95E-07	2 97E-06	6 89E-07	1 53E-06	2.73E-07	1 48E-06	2 47E-07	1 91E-06	3.53E-07
Total Site Exposure (µg/kg bw/day)			1 07E-05	1 77E-06	4 84E-06	9.95E-07	2 97E-06	6 89E-07	1.53E-06	2.73E-07	1.48E-06	2.47E-07	1.91E-06	3.53E-07
Cancer Risk Level (CRL)			3.28E-08	5 42E-09	1 34E-07	2 75E-08	1.28E-07	2 96E-08	7.52E-08	1.34E-08	4 54E-07	7.58E-08	8 23E-07	1.52E-07

EXPOSURE AND RISK ASSESSMENT MODEL (ERAM Version 1.1-D)

DELORO VILLAGE ASSESSMENT

CHEMICAL CONCENTRATIONS

BORON										
LOCATION	*BACKGROUND*			*Village*			*On-site*			
SCENARIO	plausible max	mean (typical)	stochastic	plausible max.	mean (typical)	stochastic	plausible max	mean (typical)	stochastic	
SOURCE	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	*linked*	
MEDIA										
SOIL (ug/g)	1.70E+01	1.40E+01	1.57E+01	3.08E+02	1.11E+02	4.72E+02	1.75E+00	1.37E+00		
OUTDOOR AIR (ug/m^3) - winter	7.00E-03	1.00E-03	3.96E-03	2.03E-04	1.70E-04	2.71E-04	3.50E-08	1.37E-07		
OUTDOOR AIR (ug/m^3) - summer	7.00E-03	1.00E-03	2.33E-03	2.03E-04	1.70E-04	1.06E-04	3.50E-08	1.37E-07		
INDOOR AIR (ug/m^3) -winter	5.25E-03	7.50E-04	2.97E-03	1.52E-04	1.28E-04	2.03E-04				using Roberts 1974, 75% of outdoor air is indoor
INDOOR AIR (ug/m^3) -summer	5.25E-03	7.50E-04	1.75E-03	1.52E-04	1.28E-04	7.94E-05				
INDOOR DUST (ug/g) - winter	6.63E-01	5.46E-01	6.14E-01	1.20E+01	4.34E+00	1.84E+01				using Hwang and Calabrese approximately 39% of soil conc. Is dust conc
INDOOR DUST (ug/g) -summer	6.63E+00	5.46E+00	6.14E+00	1.20E+02	4.34E+01	1.84E+02				Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
ROOT VEGETABLES (ug/g wet weight)	6.80E-02	5.60E-02	6.29E-02	4.00E-01	1.45E-01	6.14E-01				Background HGP based on Baes, then converted to fresh weight according to Mercury report
OTHER VEGETABLES (ug/g wet weight)	2.72E-02	2.24E-02	2.52E-02	1.11E+00	4.00E-01	1.70E+00				used lettuce concentrations
FRUIT (ug/g wet weight)	1.07E-01	8.79E-02	9.88E-02	4.35E+00	1.57E+00	6.68E+00				assuming same as onsite lettue dry weight and adjusting by average fruit moisture content
WELL WATER (ug/L)				5.10E+00	5.10E+00	2.50E+00				
MUNICIPAL WATER SUPPLY (ug/L)				5.10E+00	5.10E+00	5.10E+00				
BACKGROUND WATER SUPPLY (ug/L)	1.00E+00	5.00E-01	7.79E-01							

CHEMCAL TOXCITY DATA	BORON		
	plausible max	mean (typical)	stochastic
Inhalation Bioavailability	*0.73*	*0.73*	*0.34*
Oral Bioavailability of Food	0.9	0.9	0.8
Oral Bioavailability from Water	0.95	0.95	0.95
Oral Bioavailability from Soil	1	1	0.14
Oral Bioavailability from Dust	0.19	0.19	0.19
Dermal Bioavailability	0.0006	0.0006	0.0019
Inhalation Study Bioavailability	0.73	0.73	0.34
Oral Study Bioavailability	1	1	0.95
TOXICITY DATA	TYPE	VALUE	
Carcinogen (yes/no)	no		
Inhalation Exposure limit (ug/kg bw/day)	RfD	1.14E+00	
Oral Exposure limit (ug/kg bw/day)	RfD	1.80E+01	

Winter Lowering Factor - unitless	1.00E 01
Acceptable Risk Level	1.00E-06
Chemical Specific soil vegetation Transfer Factor	0.04
Site and Chemical Specific Root BTF - Max	0.013
Site and Chemical Specific Root BTF - Mean	0.013
Site and Chemical Specific Root BTF - Range	0.013
Site and Chemical Specific Vegetation BTF - Max	0.09
Site and Chemical Specific Vegetation BTF - Mean	0.09
Site and Chemical Specific Vegetation BTF - Range	0.09
Dry to wet weight conversion factor for root type veg	0.1
Dry to wet weight conversion factor for other veg	0.04
Dry to wet weight conversion factor for fruits	0.157
Fraction of arsenic that is inorganic in vegetation	0.1

	I	J	K	L	M	N	O	P	Q

		On-site	
	max.	mean (typical)	stochastic
	d	linked	linked
	-00	1 37E+00	
	08	1 37E-07	
	08	1 37E-07	

using Roberts 1974, 75% of outdoor air is indoor

using Hwang and Calabrese approximately 39% of soil conc. Is dust conc.
Have applied a 10% reduction factor on inside dust (ug/g) concentrations to be consistant with outdoor soil
Background HGP based on Baes, then converted to fresh weight according to Mercury report
used lettuce concentrations
assuming same as onsite lettue dry weight and adjusting by average fruit moisture content

C	D	E	N	O	P	Q
spasser Scenario - Only						
ɔro Exposure (µg/kg bw/d)		**AP**	**ADULT**		**COMPOSITE**	
rministic Scenario			**max**	**mean**	**max**	**mean**
ɔasser-inhalation		**x**	9.84E-11	2.66E-10		
ɔasser-oral		**x**	7.84E-05	1.76E-05		
ɔasser-dermal		**x**	1.46E-06	5.55E-07		
lation Pathway (Site)			9.84E-11	2.66E-10		
stion/Dermal Pathways (Site)			7.99E-05	1.82E-05		
l Site Exposure (µg/kg bw/day)			7.99E-05	1.82E-05		
imated Exposure Ratio (ER)			4.44E-06	1.01E-06		

C	D	E	F	G	H	I	J	K	L	M	N	O	P	O
Trespasser Scenario - Only			***BORON***											
			COMBINEO RECEPTOR											
Deloro Exposure (µg/kg bw/d)		**AP**	INFANT		PRESCHOOL CHILD		CHILD		ADOLESCENT		ADULT		COMPOSITE	
Deterministic Scenario			**max**	mean	**max**	mean	**max**	mean	**max**	meen	**max**	mean	**max**	mean
Trespasser-inhalation		x	1.19E-10	4 50E-10	2 59E-10	6.70E-10	1.87E-10	5.24E-10	1.18E-10	3.15E-10	9.84E-11	2.66E-10		
Trespasser-oral		x	1 35E-03	4 23E-04	4 96E-04	2 10E-04	2.49E-04	1.34E-04	6.85E-05	2.08E-05	7.84E-05	1.76E-05		
Trespasser-dermal		x	2.75E-06	9 97E-07	2.40E-06	8.43E-07	2.03E-06	6.96E-07	1.64E-06	6 01E-07	1.46E-06	5.55E-07		
Inhalation Pathway (Site)			1 19E-10	4 50E-10	2.59E-10	6.70E-10	1.87E-10	5.24E-10	1.18E-10	3.15E-10	9.84E-11	2.66E-10		
Ingestion/Dermal Pathways (Site)			1.35E-03	4 24E-04	4 98E-04	2.11E-04	2.51E-04	1.35E-04	7.01E-05	2.14E-05	7.99E-05	1.82E-05		
Total Site Exposure (µg/kg bw/day)			1.35E-03	4 24E-04	4 98E-04	2 11E-04	2.51E-04	1.35E-04	7.01E-05	2.14E-05	7 99E-05	1.82E-05		
Estimated Exposure Ratio (ER)			7 53E-05	2 36E-05	2.77E-05	1 17E-05	1.39E-05	7.49E-06	3 90E-06	1.19E-06	1.44E-06	1 01E-06		